technical note

Chicago O'Hare Simultaneous ILS Approach Data Collection and Analysis

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16. Abstract

Data on aircraft executing Simultaneous ILS Approach in Instrument Meteorological Conditions were collected at Chicago O'Hare International Airport (ORD) between January 24 and March 14, 1989, for the purposes of analyzing the Instrument Landing System (ILS) navigational characteristics of these aircraft. Aircraft position data were collected using the in-place ORD Airport Surveillance Primary and Secondary radars. The data were reduced and analyzed at the FAA Technical Center to provide a measure of dispersion about the approach centerline and containment within various zones and envelopes of interest surrounding the approach centerline. Conclusions concerning the approach flight characteristics are drawn and recommendations are made concerning potential applications.

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EXECUTIVE SUMMARY

Air travel delays are a major problem facing the traveling public. The Federal Aviation Administration (FAA) is investigating both long and short term ways to help alleviate this problem. One of the proximate causes for delay is related to the reduction of airport capacity during Instrument Meteorological Conditions (IMC) where the number of arrivals that can be accepted falls far below that attained during Visual Meteorological Conditions (VMC). In the long term, it is highly likely that more airports and/or additional runways at existing airports will need to be built. In the short term, innovative ATC procedures incorporating advances in technology are being considered in order to utilize existing runways more efficiently. One such short term proposal is to simultaneously use multiple runways for arrivals in cases where presently not permitted. Several pertinent questions must be answered before current regulations are changed however.

One aspect that needs to be considered is the establishment of bounds or limits on aircraft/pilot performance during worst case flight scenarios. To accomplish this, it is necessary to characterize the Instrument Landing System (ILS) navigational performance of a typical mix of today's aircraft, and to determine the degree of containment within several hypothetical Normal Operating Zones (NOZ) smaller than presently allowed. With these objectives in mind, this study has compiled a data base of targets-of-opportunity conducting simultaneous ILS approaches to parallel runways during IMC.

Chicago O'Hare was chosen as the candidate airport because of its six pairs of parallel ILS-equipped runways, its volume of traffic, and its likelihood of IMC occurrence. The O'Hare Airport Surveillance Radar (ASR)-7 and Air Traffic Control Beacon Interrogator (ATCBI)-4 radar were used as the aircraft position measuring device after extensive preliminary work was done to determine their suitability for this study. Actual data collection occurred between January 24 and March 14, 1989. The radar provided a report of range, azimuth and altitude for each target navigating in a predetermined approach zone every radar scan (4.7 seconds). Time of day, synchronized with the National Bureau of Standards WWVB radio time standard, was appended to each report. Other data collected consisted of interfacility arrival messages, airport weather sensor data including runway visibility, cloud height, wind gusts, and altimeter setting, as well as National Weather Service (NWS) surface reports. Audio recordings were also made of controller/pilot communications. On-site project personnel monitored weather and ATC procedures to determine when conditions warranted data collection.

The data were reduced at the FAA Technical Center. Individual approach tracks were constructed by extracting target reports according to beacon code from the radar data stream. Beacon codes for each arriving flight were obtained from the interfacility arrival messages. The tracks were then processed by several computer programs to identify those with missing and/or garbled reports, to correct unreasonable Mode C altitudes, to transform to cartesian coordinates and translate the origin to the runway threshold being approached, to filter and smooth the track, and to produce interpolated points at specific distance increments along the approach. An ASCII format file was output for each track to be used in the analysis. A Master data base was constructed using Foxbase. A separate record was written to this data base for each

track. This record contains all pertinent data about the track including the aircraft call sign, aircraft type, date, time-of-day of approach start and stop, current weather conditions, and certain aspects important to analysis.

Analysis consisted of considering the tracks in different ways depending on the definition chosen for ILS Localizer acquisition. Three methods were used to edit the individual tracks and combine them into groups. These groups are called View 1, View 2, and View 3, and are similar to those used in the 1985 Memphis Data Collection (Buckanin, D. and Biedrzycki, R., "Navigation Performance of Aircraft making Dependent Instrument Landing System (ILS) Approaches at Memphis International Airport, "DOT/FAA/CT-TN86/59, February 1987). Each successive view removes slightly more data from the approach's localizer acquisition phase. View 1 uses a very liberal definition of when the track has first achieved ILS stability, whereas, View 3 uses a very strict definition. View 1 includes some turn-on and all initial overshoot. View 2 includes either a small amount of initial overshoot or, if there was no initial overshoot, a small amount of turn-on. View 3 contains only the View 2 tracks with initial stability points of 10.5 miles or more from touchdown. Thus, View 3 is a subset of View 2. The views provide a means to compare ILS "navigation" with and without the turn on, and initial overshoot portion. They are also used because of the difficulty in determining the precise point of initial localizer stability for a particular aircraft.

The data base consists of 3197 simultaneous ILS approaches. These were collected on five sets of parallel approaches (10 ILS's) over an 8 week period. Approximately two-thirds of the data were collected on runway pairs separated by 5400 feet; the remaining third to runways with 6510 or 10,000-foot separation. Seventy-nine percent were large air carrier, 18 percent were air taxi, and 3 percent were general aviation. Ninety percent were collected under cloud ceilings of less than 1100 feet and/or visibilities of less than 2 miles.

The analysis showed that after stabilization on the ILS localizer (View 2) dispersion about the ILS steadily decreases from a standard deviation of about 300 feet at 13 miles to about 60 feet at 1 mile from touchdown. If the results are extrapolated to hypothetical runways having a 3100-foot separation, 96 percent of the tracks would be contained within the 550-foot NOZ, 2 percent would enter the NTZ, and the remaining 2 percent would leave the NOZ away from the NTZ. Aircraft that had stabilized before descending (i.e., by 10.5 miles from touchdown) (View 3), exhibited consistently less dispersion about the ILS than the overall population. Air taxis exhibited significantly more dispersion than the large air carriers. No significant difference was found in the ILS dispersion between any of the 10 runways considered.

The data generally supports the notion that current ILS navigation performance of a typical mix of aircraft types at a large airport could support a decreased runway separation over what is currently permissible during IMC. It must be remembered, however, that aircraft navigation performance is but one of the parameters to be considered in the overall safety and decision-making process. A model of simultaneous ILS approach collision risk, which incorporates this navigation performance with other factors important to the detection and resolution of potential aircraft overlap situations, should be used to analyze the entire system of instrumentation, procedures, and

personnel. This model is being developed in parallel with this study and it should more accurately determine the impact of the results contained herein to the overall capacity problem.

Other recommendations were also made based on work performed in this study:

1. Further analysis should be performed on the data to determine the underlying causes of significant variations in navigational performance when comparing same aircraft types under similar conditions.

2. Analysis should be performed on the data to establish the quality of the radar surveillance (garbling effects, missing or erroneous Mode C altitude, missing scans, range biases, etc.). These data should be used to develop a radar model for simulation use.

3. An enhanced radar tracking capability should be pursued, particularly using the ASR-9 and Mode S radars.

4. An evaluation should be done on aircraft transponder performance. An evaluation should also be done at candidate airports to establish radar performance. The effects of transponder variations can be minimized by siting the radar between the parallel runways.

5. The data should be used to develop a better ILS model for simulation use.

6. A monitor controller display that is sharp, clear, and uses a single symbol for each target needs to be developed. A controller alert capability would also be helpful.

7. The project team would like to collaborate and share their findings with others working in this area. This is a complex problem spanning a wide range of issues.

1. INTRODUCTION.

There is currently great interest in reducing air travel delays along with their economic and productivity costs. Travelers, the airlines, the press, and Congress have all expressed concern. Efforts to alleviate the problem in the past have included a redesign of the airways, central flow management, further automation of the air traffic control (ATC) system as well as better utilization of existing facilities. There continues to be calls for adding runways to existing airports, or even to build more airports to increase system capacity in order to reduce delays.

The Concepts and Analysis Division, ACD-300, of the Federal Aviation Administration (FAA) Technical Center has been investigating ways to reduce delays by utilizing innovative ATC procedures and incorporating advances in technology rather than building additional runways or facilities. One proposed procedural technique to decrease delays is to increase the concurrent use of multiple runways. However, this has historically been a difficult problem to solve since it ultimately involves safety issues. ATC surveillance performance, aircraft/pilot performance, communications delays, ATC intervention rate, and satisfactory missed approach procedures are some of the confounding systems factors involved.

One key task would be to establish the limits of aircraft/pilot performance during worst case scenarios. This would accomplish two things: (a) it would give insight into the controller intervention rate necessary during periods of difficult ATC operations, and (b) establish the reasonableness of reducing the size of the current Normal Operating Zone (NOZ). This could be done by characterizing the navigational performance of a typical mix of aircraft operating in a busy terminal environment during hours of adverse weather conditions. With this in mind, the Terminal Concepts and Studies Program has compiled and analyzed a data base of aircraft conducting simultaneous instrument landing system (ILS) approaches to parallel runways at O'Hare International Airport during instrument meteorological conditions (IMC). The results of that analysis are the subject of this report.

1.1 BACKGROUND.

Many different phrases have historically been used both by policy makers and researchers to refer to simultaneous independent instrument approaches to closely spaced parallel runways. For the purpose of consistency and brevity, the phrase simultaneous ILS approaches will be used for this report. Additional information about simultaneous ILS approach procedures reprinted from the FAA Air Traffic Control Handbook (reference 1) can be found in appendix E.

1.1.1 The Problem.

Air travel delays resulting from limited airport capacity during periods of peak traffic and adverse weather conditions are a significant problem. Some have proposed increasing airport capacity through either the construction of new airports or the expansion of existing facilities. Unfortunately, the high cost of land acquisition, terrain constraints, local zoning ordinances, and noise abatement policies, as well as the substantial social and political resistance, makes this solution extremely limited.

The airport capacity problem is intensified by the onset of inclement weather, especially for aircraft arrivals (reference 2). A primary reason for this is that many runway configurations usable during visual meteorological conditions (VMC) become unusable during periods of IMC. Many airports, which are currently able to employ up to three arrival runways in good weather, may become restricted to as little as one arrival runway when the weather worsens. During IMC, the only multirunway arrival configuration that can be employed is when both runways are parallel. Furthermore, current regulations stipulate that only parallel runways with at least 4300 feet between runway centerlines may be used for simultaneous (independent) aircraft approaches. This requirement restricts arrival capacity not only at airports with parallel runways separated by less than 4300 feet, but also at those which do not have the space needed to add a runway parallel to an existing one.

A practical alternative to the addition or expansion of existing facilities is the reduction of the current minimum separation requirement to as little as 3000 feet. This argument is based on the assumption that the rate of improvements in ATC related equipment and procedures will allow such a reduction without compromising the level of safety attained with the existing standard. A quantitative assessment of the risk involved in simultaneous parallel approaches is required in order to both measure this standard and ascertain how other separations, procedures, and equipment configurations may affect the safety of operations relative to this standard.

1.1.2 Historical, Technical, and Procedural Background.

The application of parallel runway configurations to aircraft arrivals dates back to the late 1950's. The FAA sponsored several studies to analyze the ability of pilots to perform instrument flight rules (IFR) approaches to parallel runways during IMC. These studies (references 3 and 4) provided the data to permit the FAA to develop regulations in 1963 for simultaneous approaches to runways with at least a 5000-foot centerline spacing. The Chicago (O'Hare), Los Angeles, Atlanta (Hartsfield), and Miami airports were the principal benefactors of these rules. They all had existing parallel runways which could take advantage of the reduced spacing requirement (reference 5).

By the late 1960's, rapid increases in the volume of air traffic necessitated a further reduction in the runway separation requirements (reference 2). Based on additional data (reference 6) the FAA revised the regulations so that simultaneous parallel approaches could be performed on runways with a centerline spacing of at least 4300 feet. This spacing was chosen principally to allow additional simultaneous approach configurations at Atlanta and Los Angeles airports (reference 5).

In addition to the minimum 4300-foot centerline spacing, the following four requirements must be met for the authorized use of simultaneous ILS approaches (reference 7):

a. An operating ILS, radar, and two-way radio communications link.

b. Aircraft must be separated by a minimum of 1000 feet vertically or 3.0 nautical miles (nmi) on radar until established on their respective localizer courses.

c. Two monitor controllers must be used to ensure lateral separation between aircraft and to intercede in the event of an aircraft blunder.

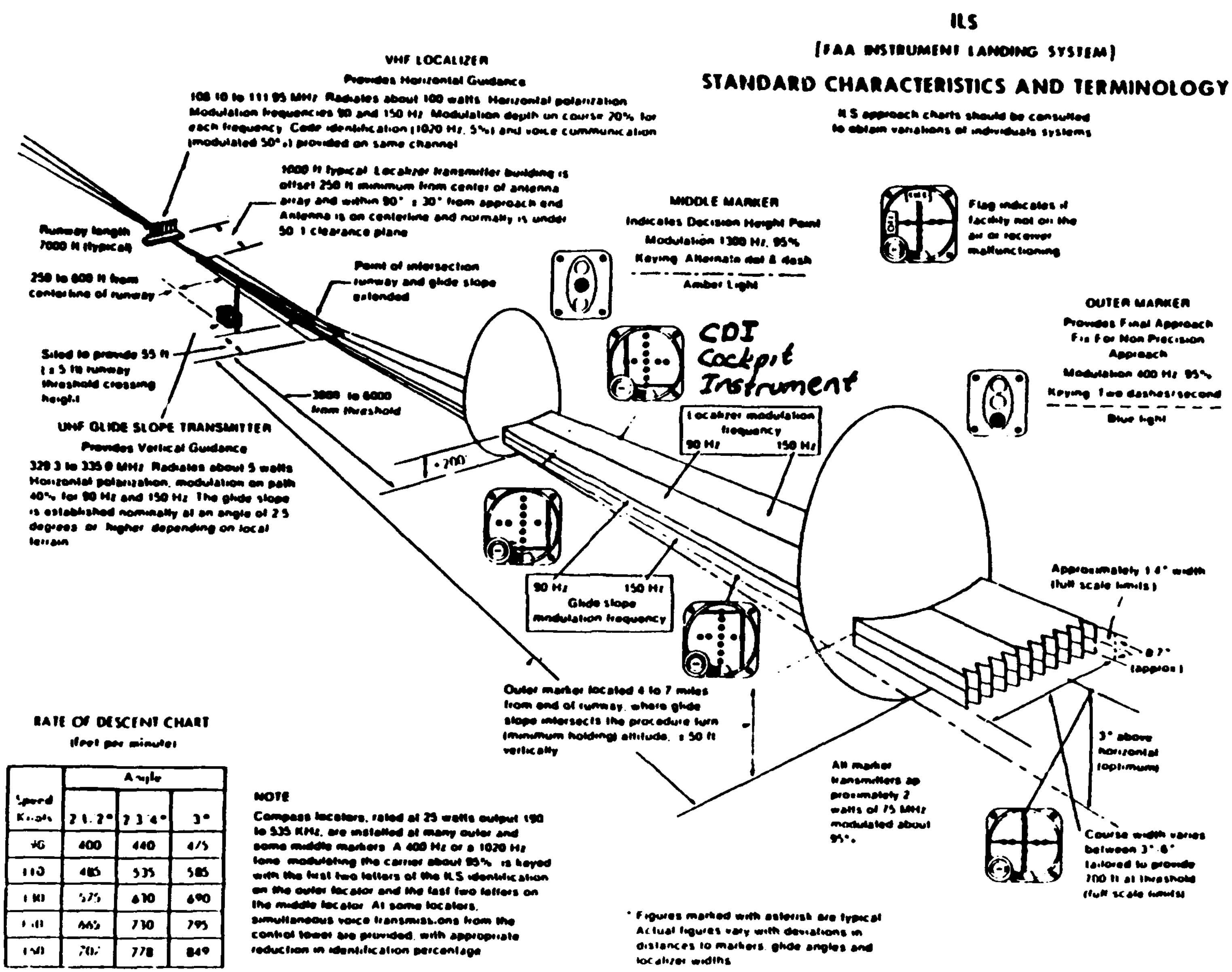
d. A 2000-foot wide No Transgression Zone (NTZ) centered between the two extended runway centerlines must be maintained.

The ILS consists of two independent transmitters which provide navigational guidance for aircraft executing an IFR approach. One transmitter is the localizer which radiates a 3° to 6° fan-shaped horizontal beam at 108.10 to 111.95 megahertz (MHz) that provides lateral (side to side) guidance for aircraft on final approach out to a distance of about 18 nmi. The other transmitter is the glide slope which provides a 1.4° fan-shaped vertical beam at 329.30 to 335.00 MHz that provides altitude guidance. The composite beam resulting from these transmitters defines a precise approach course for arriving aircraft. Refer to figure 1.1 for further positioning and performance characteristics of the ILS transmitters. A typical ILS also includes up to three additional marker transmitters which provide the pilot with information on his range from runway threshold. Each runway has its own independent ILS. Additional information about the ILS is contained in the final report by Ammerman, et al. (reference 8).

The approach course runs along a vector extending from the runway threshold upward at approximately a 3° angle relative to the ground. ILS approach procedures require that arriving aircraft be established on the localizer prior to intersecting the outer marker, which is typically located about 5 nmi from runway threshold. However, for simultaneous ILS approaches, this distance is typically extended to 10 nmi or more (see figure 1.2).

Aircraft executing an IFR approach are required to have an ILS receiver. This receiver tells the pilot how well the aircraft is following the prescribed approach course. ILS receivers range from the very simple Course Deviation Indicators (CDI), which indicate whether the pilot is left, right, above, or below the prescribed course (refer to figure 1.1) to the sophisticated receivers which couple with the navigational autopilot to provide for automatic flight control down to the decision height (DH). The DH is the altitude at which the pilot must be able to visually sight the landing runway. DH depends primarily on the sophistication of the installed ILS transmitters and varies from 1000 feet above ground level (Category I ILS) to ground level (Category IIIC ILS). IFR approach procedures require that if the pilot is not able to spot the runway at the DH, or if the aircraft is so misaligned that the pilot would not be able to adequately correct before touchdown, then a missed approach must be executed. For parallel approaches, the missed approach maneuver includes both a climb and a turn away from the adjacent runway. Exact missed approach procedures vary depending on the airport, type of aircraft involved, and weather conditions. A sample procedure may be found in the appendices of Haines (reference 9).

Simultaneous ILS approach procedures require two monitor controllers. Their task is to assure adequate lateral separation between aircraft on adjacent runways. One controller is responsible for aircraft on the left runway while the other is responsible for aircraft on the right runway. The monitor controllers are responsible for the aircraft only after the following has been accomplished by the final controller who vectors the aircraft onto the appropriate ILS course:



Speed Knots	Angle 2 1/2°	2 3/4°	3°
90	400	440	475
110	485	535	585
130	575	630	690
150	665	730	795
170	705	778	849

FIGURE 1.1. STANDARD CHARACTERISTICS AND TERMINOLOGY

(Taken from Ammerman [8])

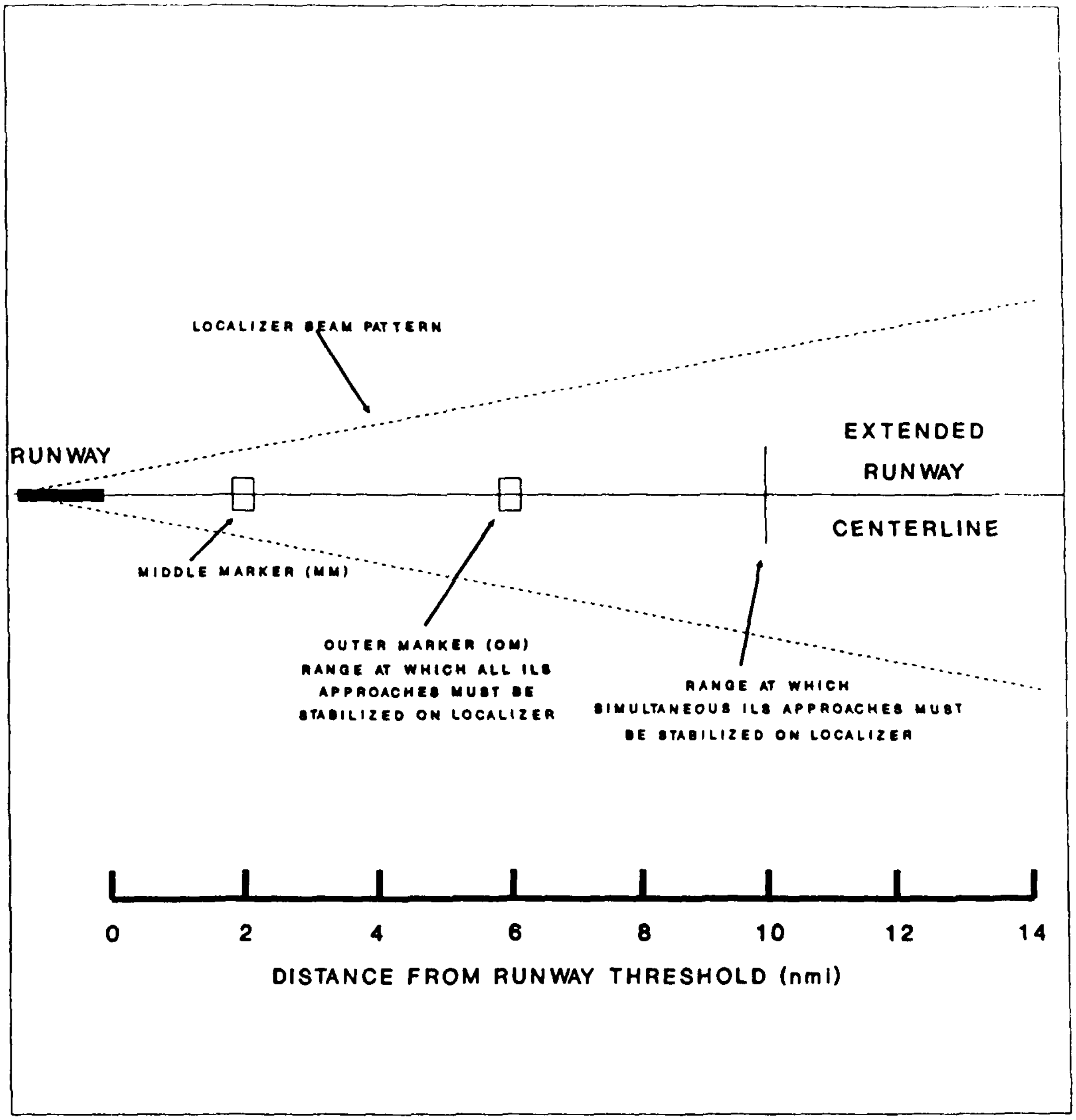


FIGURE 1.2 OVERHEAD VIEW OF A TYPICAL LOCALIZER/MARKER SETUP

a. The pilot has been given and has confirmed the local controller's radio frequency.

b. The pilot has been given and has confirmed the localizer and glide slope frequencies.

c. The aircraft has intercepted the ILS.

The monitor controllers share the radio channel of the local controller in the event that communication with the aircraft is required. The local controller is responsible for all flight in the terminal area to which visual separation can be applied.

Since the monitor controllers need to interact with each other, they use the same radar Automated Radar Terminal Systems (ARTS) display. As shown in the magnified representation of the ARTS display (figure 1.3), the monitor controllers are responsible for keeping their aircraft within their respective NOZ. See Fantoni (reference 3) for more information on the presentation of an ARTS controller display.

Most of the time, the ILS receivers and aircraft navigation systems are accurate enough to guide the aircraft directly down the approach path without significant lateral deviation to either side. However, in the event that an aircraft is observed on a track which would penetrate the 2000-foot wide NTZ, the monitor controller in charge of that runway is required to advise the pilot to "turn left (or right) and return to localizer course" (reference 1). In addition, the two controllers may work together to issue speed advisories to minimize the chance of conflict between the adjacent aircraft. When an aircraft is observed violating the NTZ in a manner which could jeopardize an aircraft on the adjacent runway approach, the monitor controller of the threatened aircraft will advise the threatened aircraft's pilot to execute a missed approach. Meanwhile, the other monitor controller will continue to attempt to have the pilot of the blundering aircraft correct his errant course.

The threatened aircraft is vectored off the ILS course instead of the blundering aircraft for two principal reasons (reference 10):

a. The pilot of the blundering aircraft has demonstrated an inability to adequately navigate and/or control the aircraft (possibly due to an inflight emergency).

b. To increase the airspace between the two conflicting aircraft to decrease the probability of collision.

Meanwhile, if the monitor controller of the blundering aircraft is unable to correct its course, then, as a last resort, it is handed off again to the final controller for resequencing into the traffic pattern.

Since most aircraft are well contained within the NOZ, most of the monitor controller's time is spent insuring longitudinal separation between aircraft on the same approach. This is accomplished through the issuance of speed advisories. The minimum longitudinal separation standard between aircraft on any ILS approach (single or parallel) is 3 nmi. However, for heavy jet

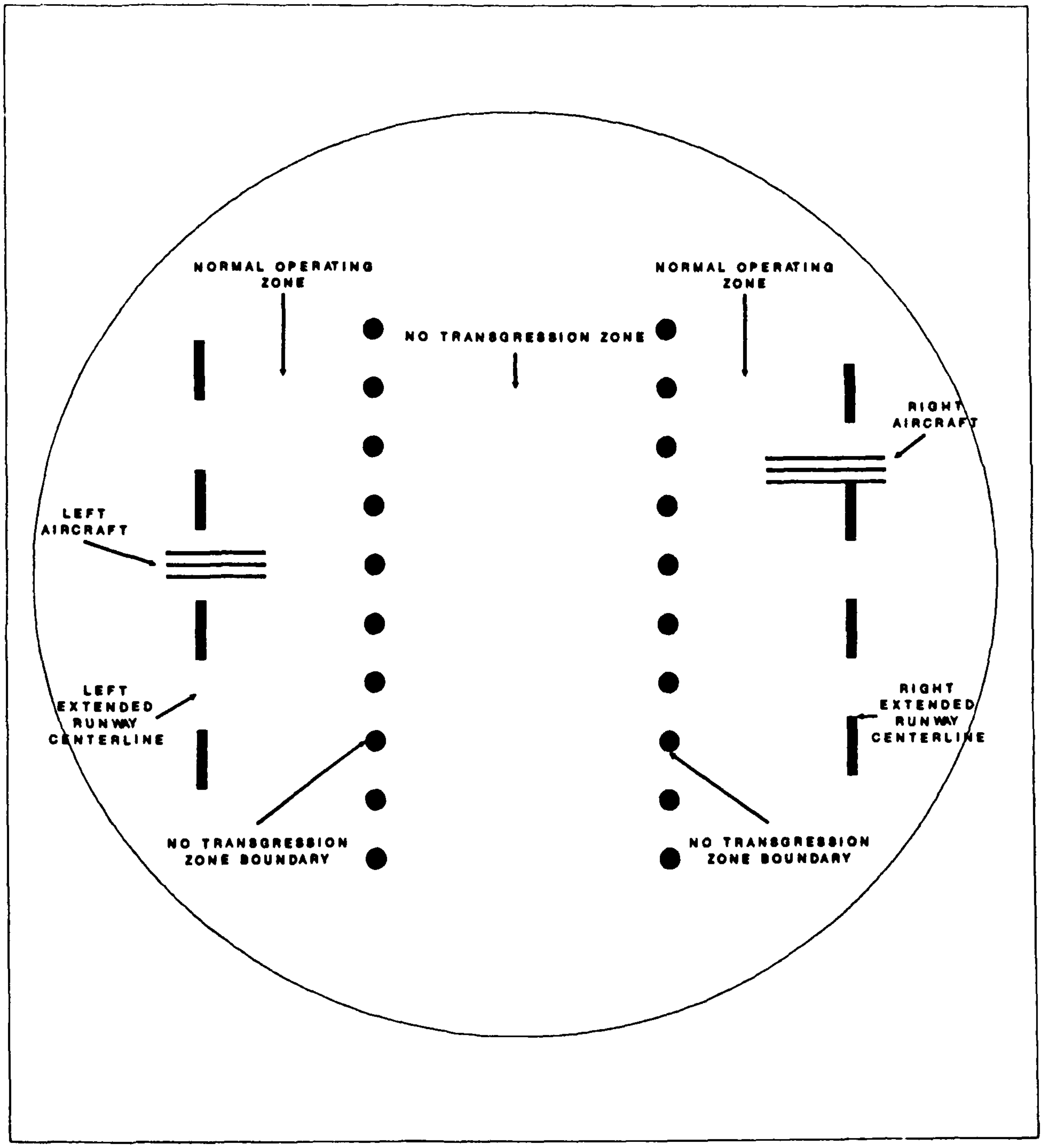


FIGURE 1.3 ENLARGED REPRESENTATION OF MONITOR CONTROLLERS' RADAR DISPLAY

aircraft, such as a DC-10 or B-747, at least 6 nmi separation is required for the trailing aircraft.

Throughout the approach operation, control responsibility routinely remains with the local controller and not with the monitor controllers unless the latter act to insure separation. The monitor controllers' normally passive function requires no communications with the pilot except during the infrequent situations when warning, advisory, or vectoring action is necessary. Since the monitor controllers share their radio frequency with the local controller, judicious use of this frequency is required. The judgment and techniques of the monitor controllers critically impact the safety and efficiency of the overall approach operation (reference 10).

1.1.3 Literature Survey of Past Data Collection Efforts.

Attempts to perform a risk analysis of simultaneous ILS approaches dates back to the late 1950's. Since that time, all the research performed in this area may be categorized into four distinct genres:

a. Data collection and analysis studies
b. Probabilistic conflict rate models
c. Parametric blunder resolution models
d. Real time simulation

These genres differ significantly in terms of the assumptions used, the variables considered, and the means by which the output is obtained. However, with few exceptions, a considerable amount of similarity exists between models in the same genre. Since this report describes a Data Collection and Analysis study, the literature survey will be limited to this particular genre. A complete literature survey may be found in Altschuler (reference 11).

The Data Collection and Analysis genre of research features the collection and analysis of data taken from direct observation of aircraft executing IFR approaches for the purpose of determining the risk involved in simultaneous ILS operations. The data produced from the collection activities are compiled to generate simple statistics such as mean, standard deviation, and percent containment for the lateral position of the aircraft with respect to the extended runway centerline. Information about the shape of the distribution is obtained from histograms and probability plots. The final output is the frequency with which the aircraft enters the adjacent approach path.

McLaughlin (references 12 and 13) collected data for single ILS approaches at ten U.S. airports. Observations were grouped by range from runway threshold, aircraft type, ceiling height, wind speed and direction, visibility, and altitude at which the aircraft spotted the runway. However, with the exception of range from runway threshold, no statistically significant effects were found for any of these parameters. McLaughlin found that the navigational error variance decreased with proximity to runway threshold. He also generated the first 4 moments from the data and determined that the shape of the distribution for lateral deviation could be approximated by a Pearson type VII function (more kurtotic than Gaussian) and that the best fit occurs at the tails of the distribution. One underlying assumption of this study was that the precision with which aircraft fly the ILS for single runway approaches was worse than or equal to the precision for simultaneous ILS

approaches (a worst case assumption). Since only single approaches were recorded, the validity of this assumption could not be determined.

The study by Fantoni (reference 3) employed the use of noncommercial test flights in order to establish a data base of performance of aircraft on simultaneous ILS approaches separated by 2700 feet. Data were also collected for commercial flights onto both single runways, and parallel runways separated by 6510 feet (Chicago O'Hare runways 14R/14L) in order to increase the size of the data base. A critical input to the study was the result of pilot and controller questionnaires which provided insight particularly to the optimal level of monitor controller interaction for the approach. Based on these results, Fantoni was able to recommend:

a. The necessary equipment configurations and the operational procedures for the 6510 separation at Chicago O'Hare airport.

b. Feasibility and operational usage of 2700-foot separated runways.

c. Future data collection and analysis requirements toward arriving at minimum runway separation criteria.

Specifically, Fantoni pointed out that simultaneous ILS approaches to runways separated by 5000 feet are operationally feasible, given the application of altitude separation at ILS intercept (turn-on) and the use of monitor controllers to advise aircraft to correct errant courses (the reason for the conclusion concerning altitude separation at turn-on is shown in figure 1.4). As a result, this study directly contributed to the enactment of the 1963 FAA Order permitting simultaneous ILS approaches at 5000-foot separations.

A little less than a decade later, Resalab (reference 6) collected data on both lateral and vertical track keeping ability for single runway approaches at Charleston, South Carolina, Airport. Although the primary purpose of these data were to initialize the state equations in their feedback control system model, these data were combined with additional data collected concurrently by other sources (for purposes other than study of runway separation) to allow the FAA to reduce the lateral separation standard from 5000 feet to 4300 feet in 1974. Based on an analysis of this (and other) data, Resalab was able to confidently conclude that the probability distribution for vertical track-keeping (navigational) errors was Gaussian, whereas, the distribution of lateral track-keeping (navigational) errors was non-Gaussian. As with McLaughlin (reference 12), Resalab also found that the navigational error variance decreased with proximity to runway threshold; they determined that this was due both to the angular spread of the localizer beam and to the increase in signal noise from the beam as it radiated from the transmitter.

Memphis International Airport was the site of a 1985 data collection study reported upon by Buckanin and Biedrzycki (reference 14). Aircraft flight tracks were recorded for dependent ILS approaches to parallel runways. Rules for such approaches are based on 1978 FAA regulations and differ from simultaneous ILS approaches as follows:

a. Monitor controllers are not used. All control after ILS intercept rests with final controller and local controller.

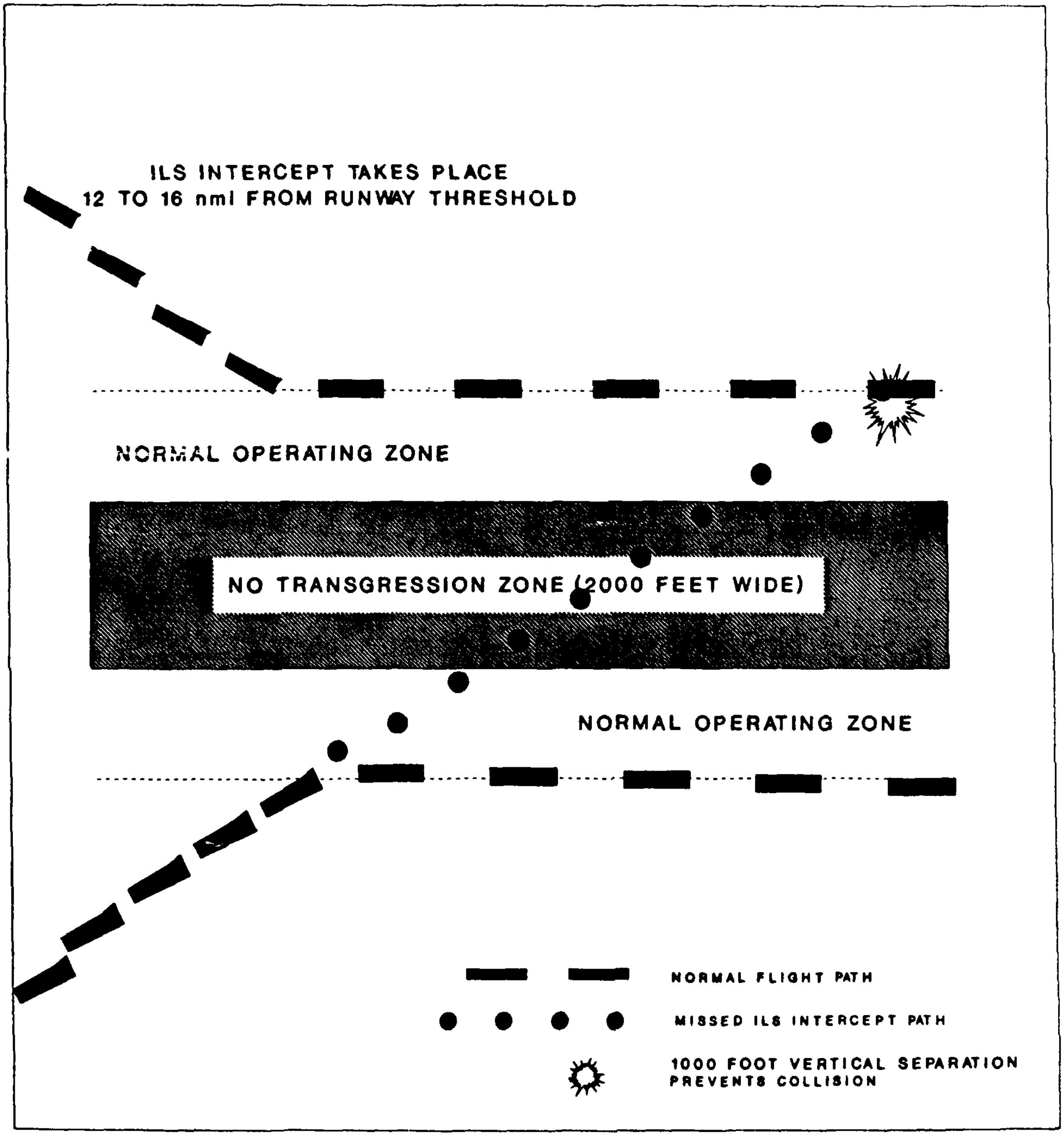


FIGURE 1.4 OVERHEAD VIEW OF SIMULATANEOUS ILS INTERCEPT PATHS

b. Two-mile radar separation is required between aircraft on adjacent runways. This results in staggered separation.

c. Dependent operations may be employed on parallel runways separated by as little as 2500 feet. However, the utility of the two runways is significantly less than a simultaneous ILS approach configuration.

Since no data on ILS approaches had been collected since Resalab (reference 6), the Airport Operations Council International (AOCI) requested that a new data base be compiled using the more sophisticated collection and recording techniques then available. Data were collected for approximately 1000 flight tracks at Memphis under IMC, and was grouped by weather conditions, wind direction and speed, ceiling height, aircraft type, range of localizer intercept, and the presence of stability before descent. Of these factors, only the last three had a statistically significant effect on the way aircraft navigate the ILS. Although one of the purposes of the study was to generate data for input into some of the existing theoretical models for simultaneous ILS approach risk estimation, the authors concluded that a data base of flight tracks from simultaneous ILS approaches would be more desirable.

1.2 PURPOSE OF THIS STUDY.

Given the stated need (reference 14) for a data base of flight tracks from simultaneous ILS approaches, the Requirements and Concepts Development Division, ADS-100, based at FAA's Washington Headquarters, tasked the FAA Technical Center's Concepts Analysis Division, ACD-300, to collect, reduce, and analyze sufficient data to meet the following objectives:

a. To characterize the navigational performance of aircraft flying simultaneous ILS approaches during periods of IMC.

b. To determine if 95 percent of these approaches would be contained within a theoretical 550-foot NOZ.

c. To perform a risk analysis of aircraft conducting these approaches.

The remainder of this report describes in detail the steps taken towards meeting the first and second objectives. The work on the third objective was undertaken in a second parallel effort reported upon under separate cover (reference 11).

2. CHICAGO O'HARE INTERNATIONAL AIRPORT.

2.1 O'HARE SIMULTANEOUS APPROACHES.

Chicago O'Hare International was chosen as the candidate airport for this study because of its six parallel ILS equipped runways, the likelihood of IMC occurring, and the significant amount of traffic handled. Table 2.1 lists the separation, inset, and NOZ width for each of the parallel runway pairs. The airport layout is shown in figure 2.1. Runway separations range from 5400 to 10000 feet.

TABLE 2.1 CHICAGO O'HARE PARALLEL RUNWAY SEPARATIONS

RUNWAY PAIR	SEPARATION	THRESHOLD INSET	NOZ WIDTH
09L-09R	5425	724 (09L)	1712
27L-27R	5405	1997 (27R)	1702
22L-22R	10055	4552 (22L)	3942
04L-04R	9610	5460 (04L)	3805
14L-14R	6509	240 (14R)	2255
32L-32R	6506	3228 (32R)	2253

NOTE: All distances are in feet

Figure 2.2 shows a typical parallel runway pair along with definitions of runway separation, runway inset, NTZ, and NOZ. Also shown are typical locations for the ILS localizer and glide slope antennas. Figures 2.3 through 2.7 show the vertical profiles of the 12 ILS glidepaths. In these figures, the abscissa (distance to runway) has been normalized such that (0,0) is at the threshold of the runway that is not inset. These figures show that the glide slope intercept altitudes are normally 4000 and 5000 feet for respective simultaneous approaches. The exception is 14L and 14R which have 4000- and 7000-foot intercepts, respectively. These intercepts provide at least 1000 feet of vertical separation until approximately 13.5 nmi from runway threshold. The vertical separation then begins to decrease nearing zero at approximately 10.5 nmi from threshold.

Figures 2.8 through 2.20 show the published approach charts for the runways to which simultaneous approaches were recorded.

2.2 SURVEILLANCE RADAR DATA.

2.2.1 Preliminary Work.

Prior data collections used stand-alone precision approach radars (PAR's) having a high degree of accuracy and resolution as well as high update rates. The data collection in Memphis, for example, used a military TPN-22 multiple object tracking radar with a resolution of 10 feet and update rate of 0.1

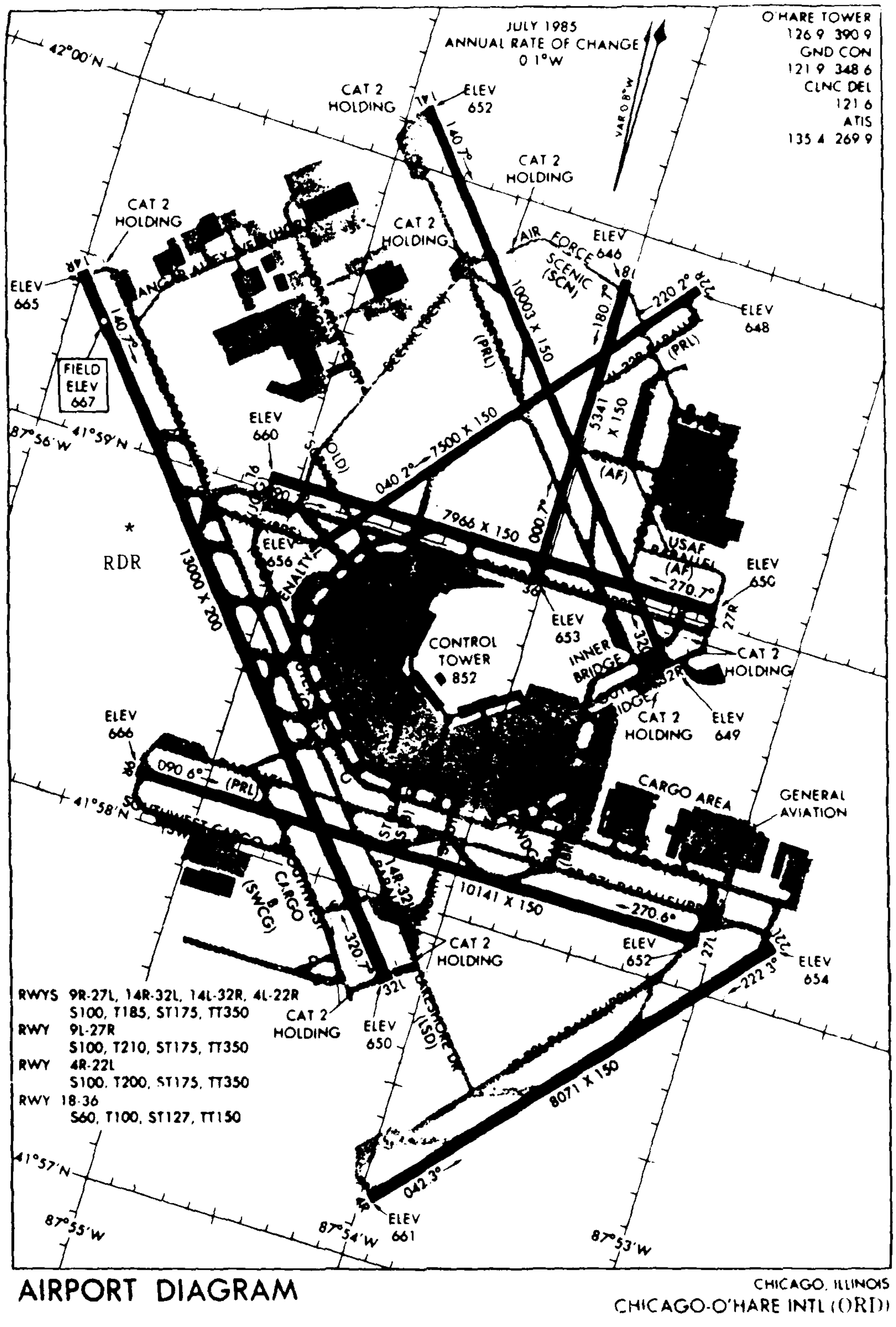


FIGURE 2.1 O'HARE AIRPORT PLATE

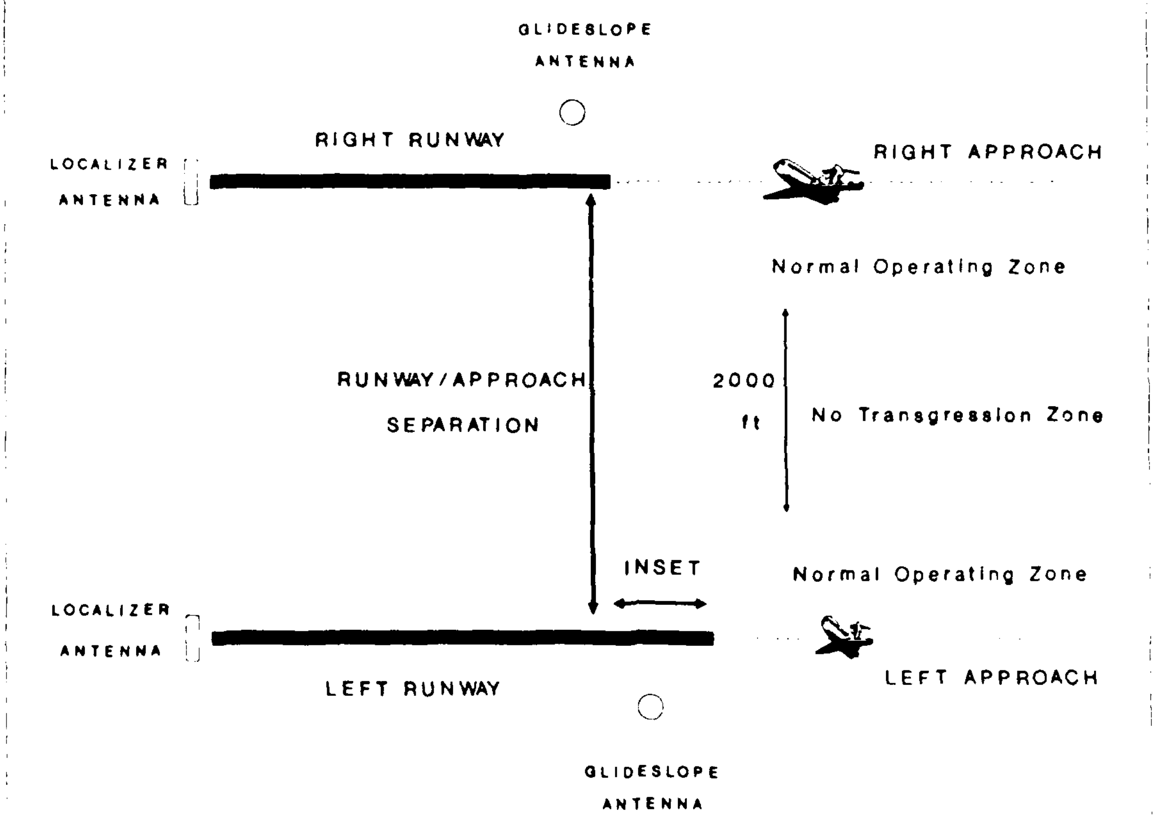


FIGURE 2.2 PARALLEL RUNWAY GEOMETRY

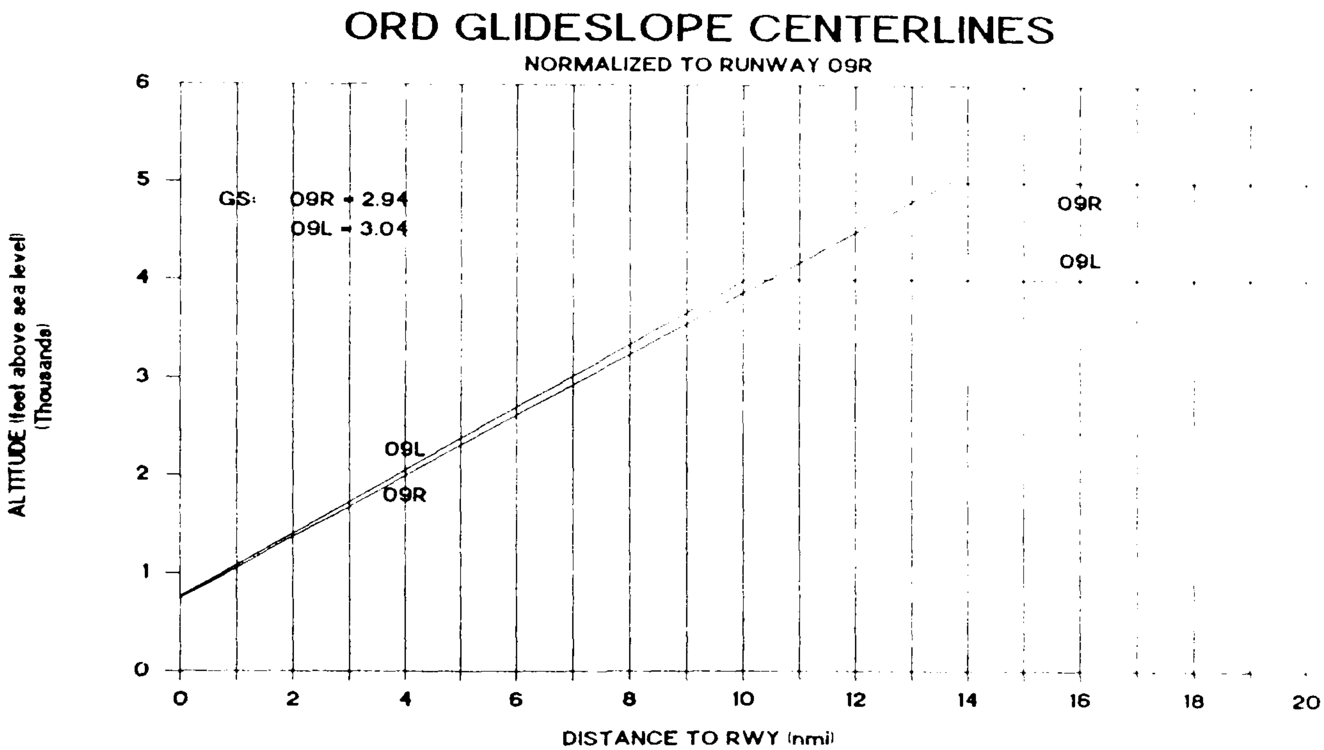


FIGURE 2.3 ILS GLIDESLOPES FOR RUNWAYS 09L/09R

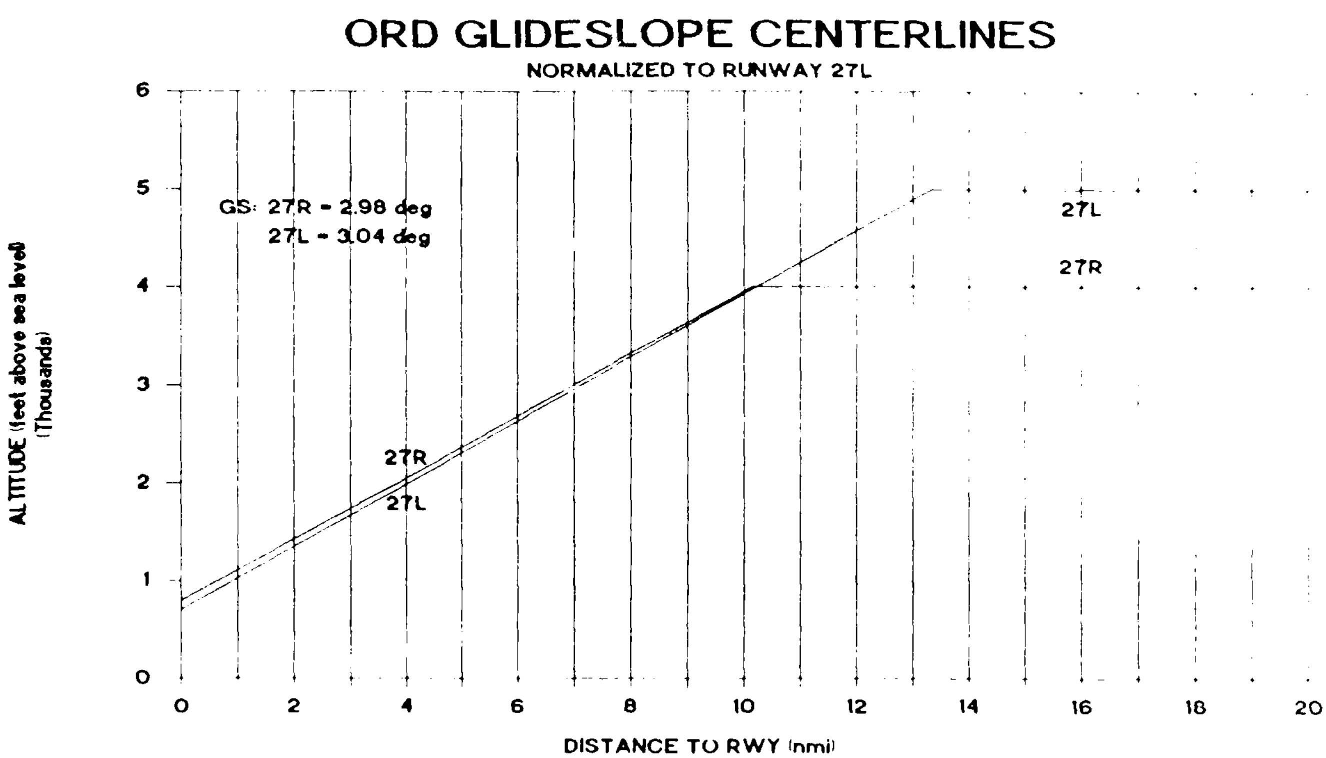


FIGURE 2.4 ILS GLIDESLOPES FOR RUNWAYS 27L/27R

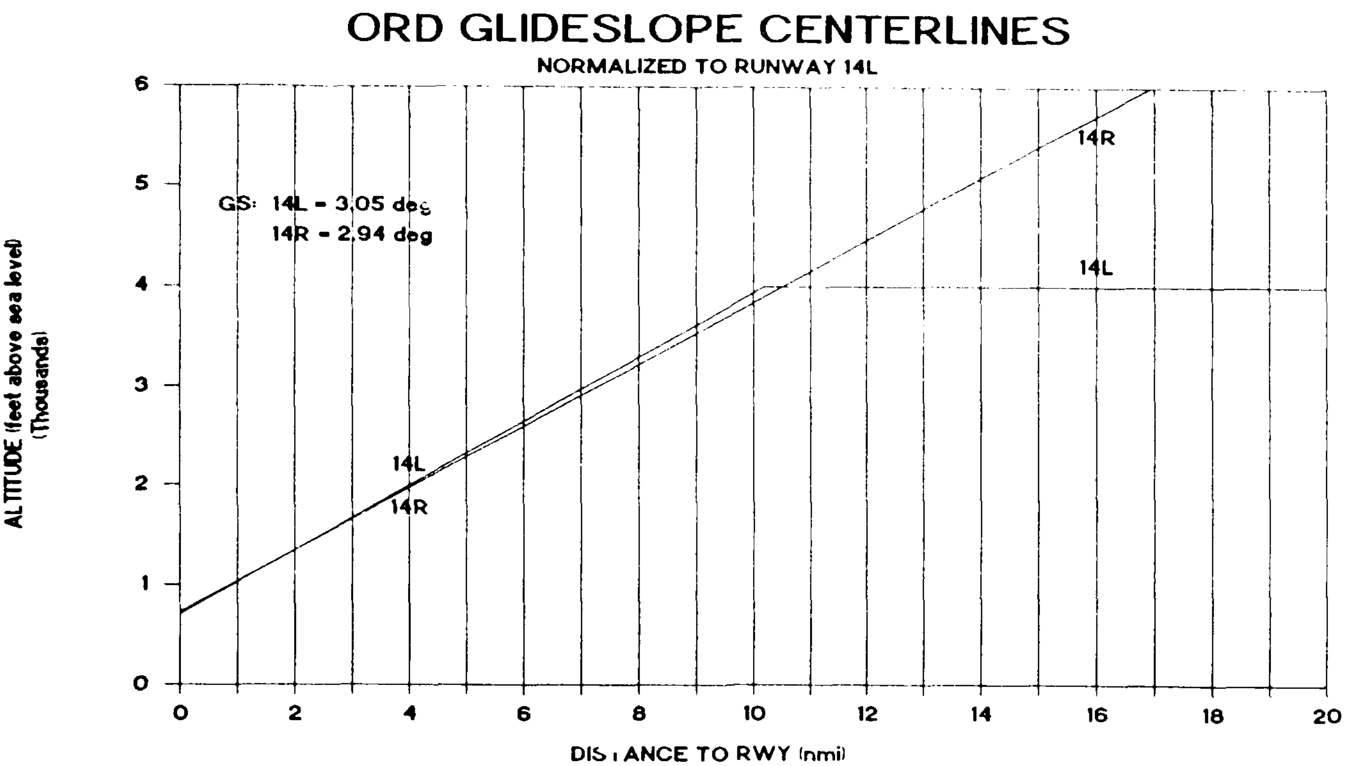


FIGURE 2.5 ILS GLIDESLOPES FOR RUNWAYS 14L/14R

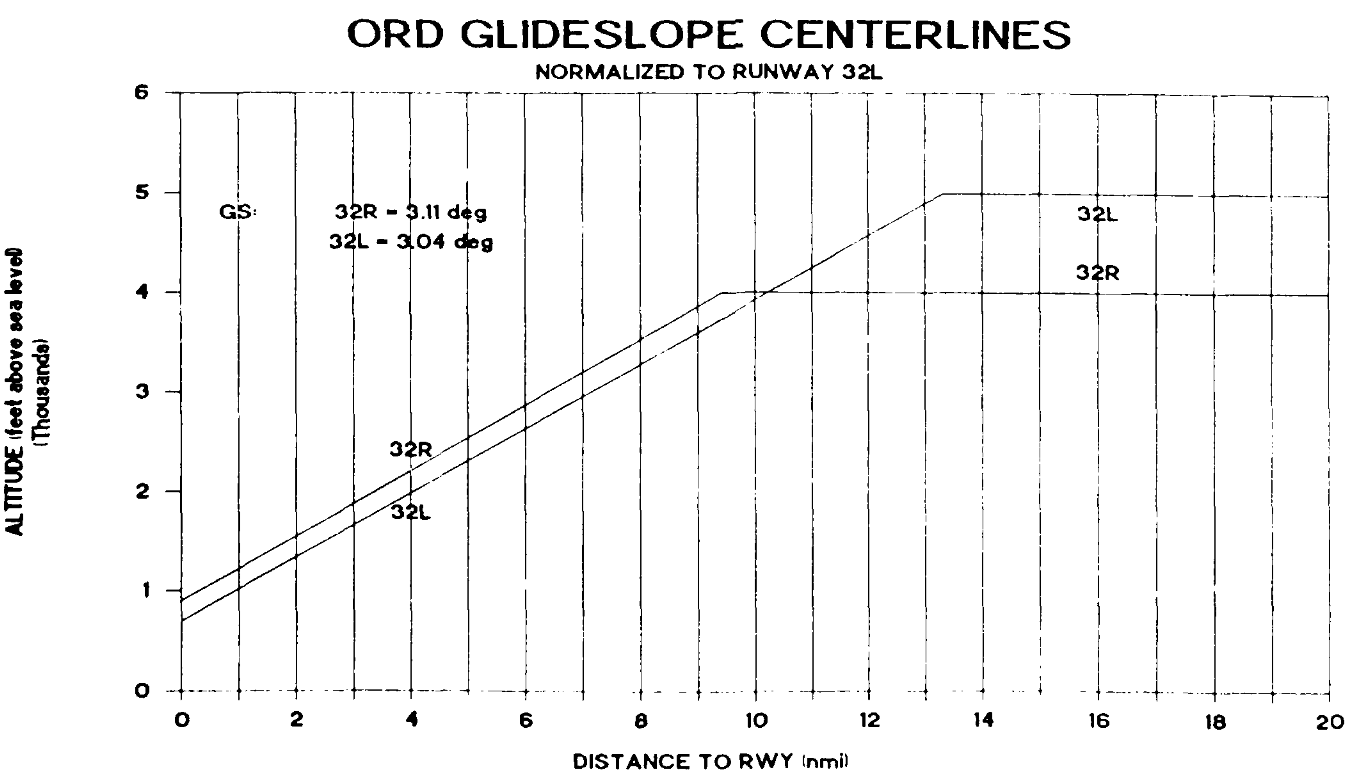


FIGURE 2.6 ILS GLIDESLOPES FOR RUNWAYS 32L/32R

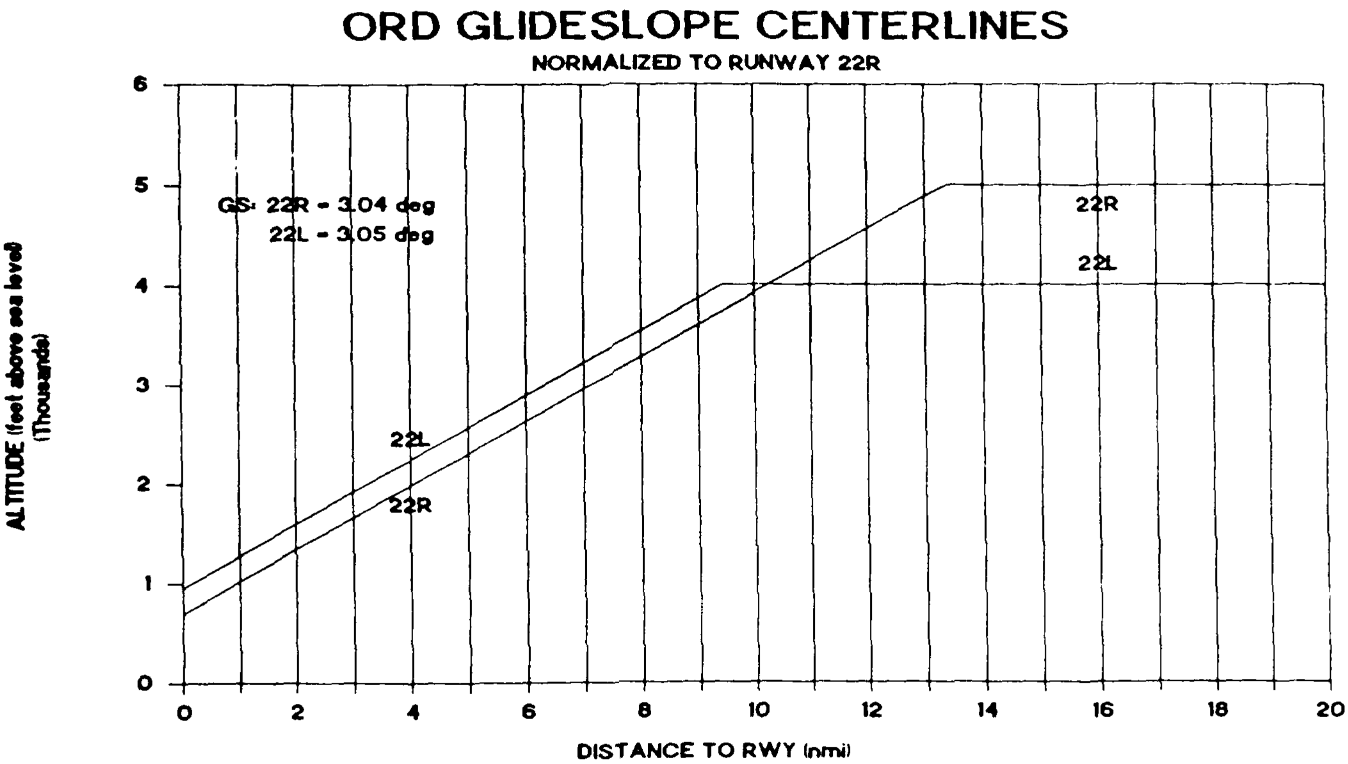


FIGURE 2.7 ILS GLIDESLOPES FOR RUNWAYS 22L/22R

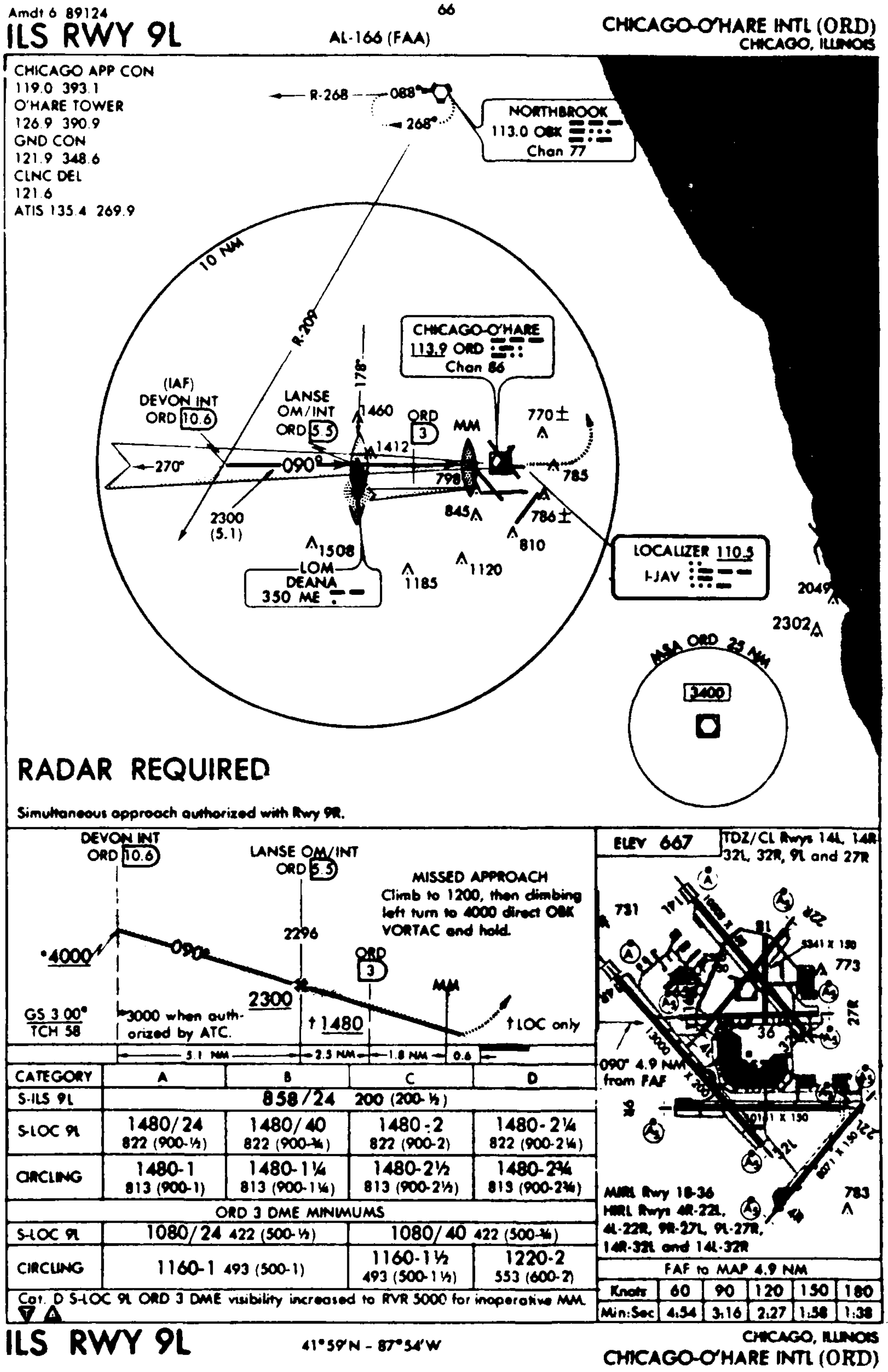


FIGURE 2.8 RUNWAY 09L ILS APPROACH CHART

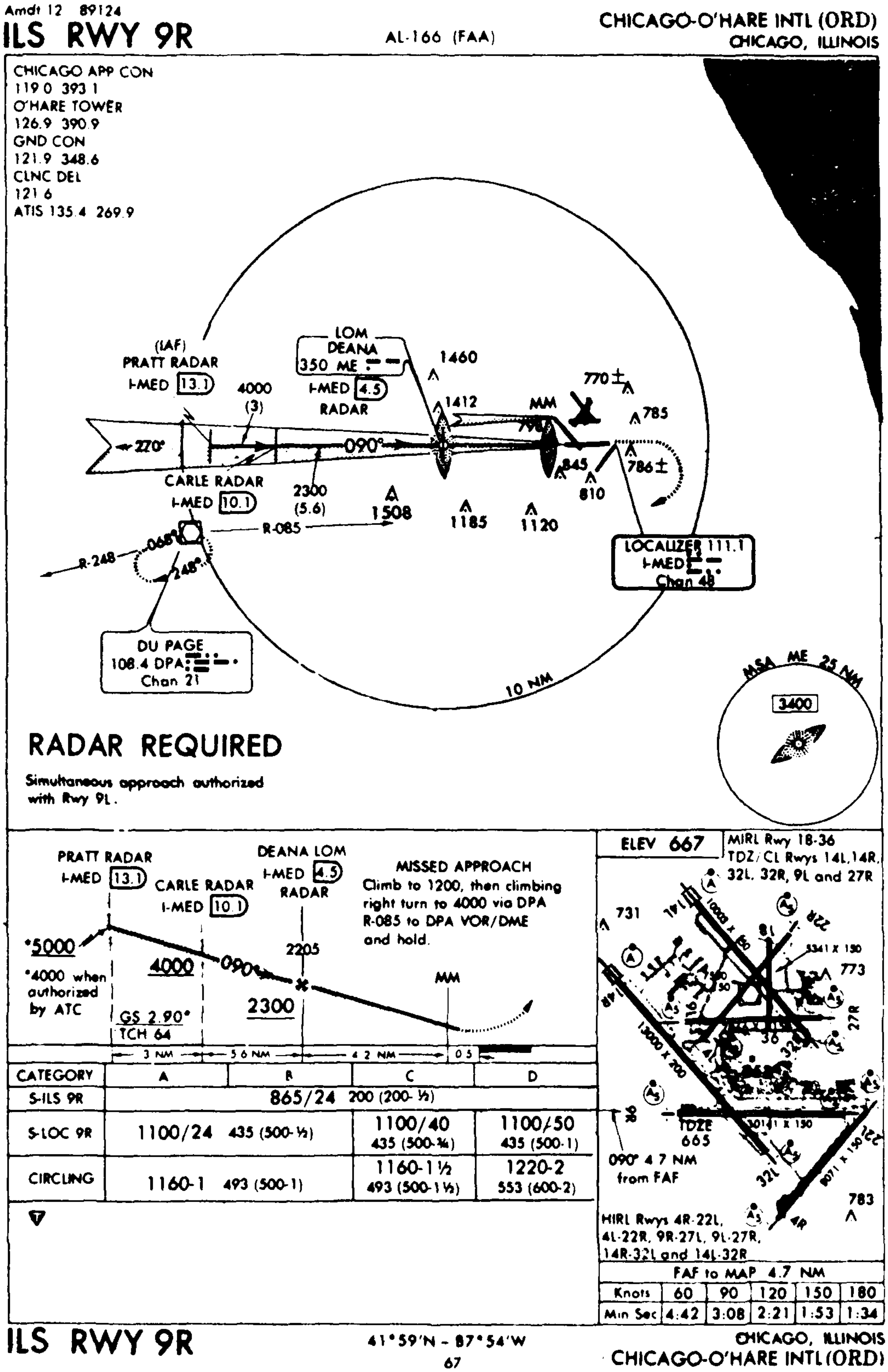


FIGURE 2.9 RUNWAY 09R ILS APPROACH CHART

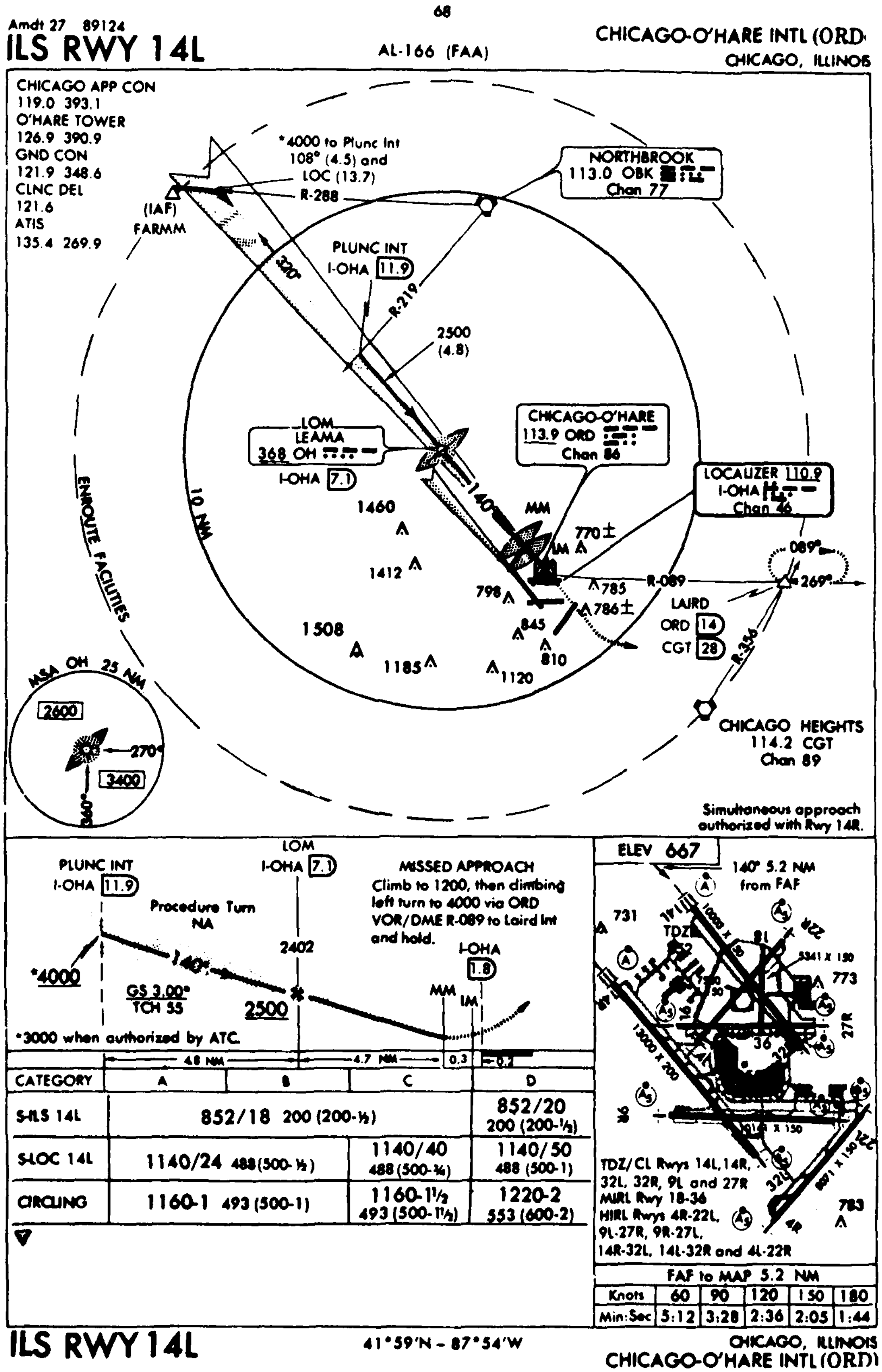


FIGURE 2.10 RUNWAY 14L ILS APPROACH CHART

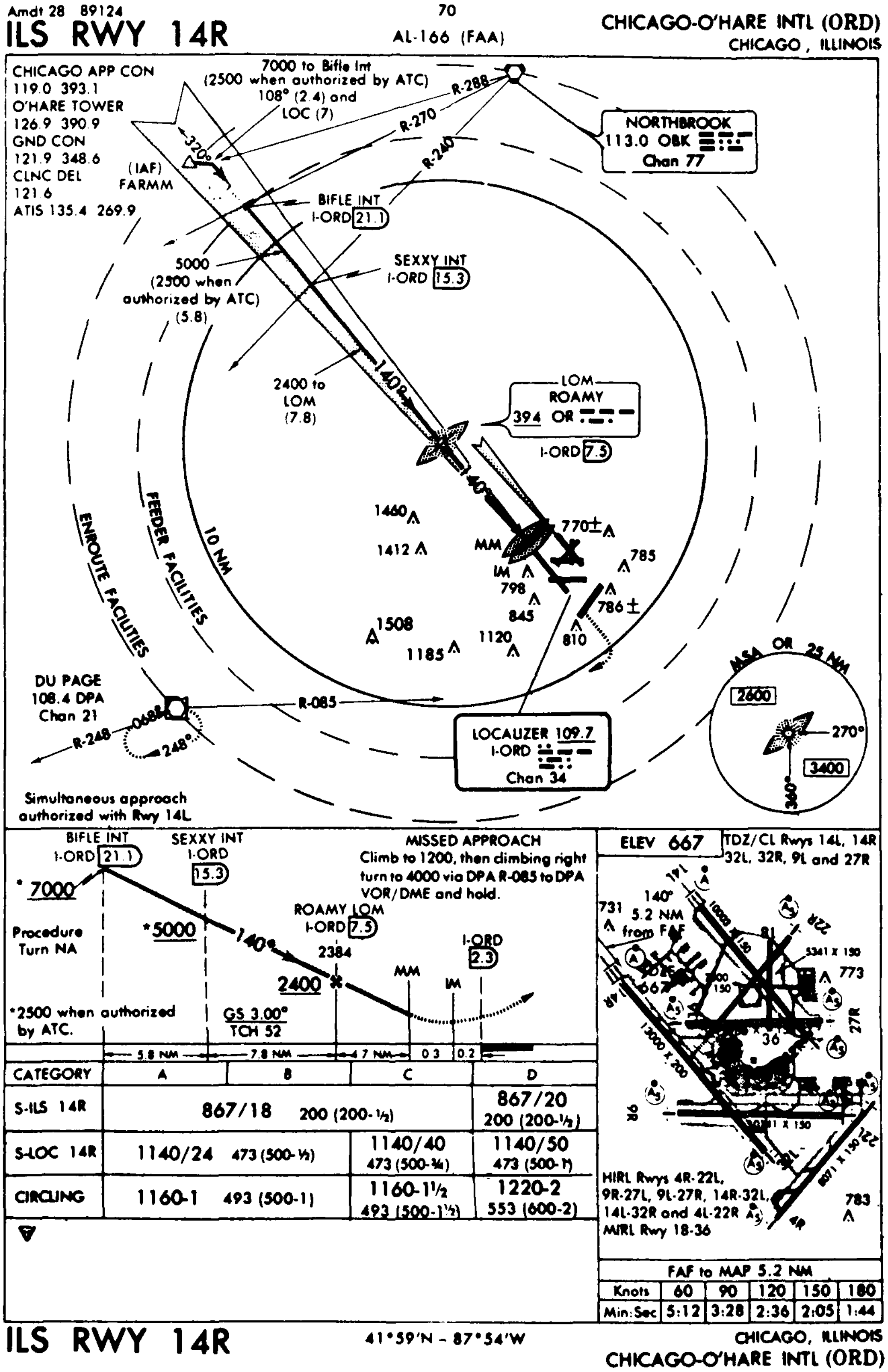
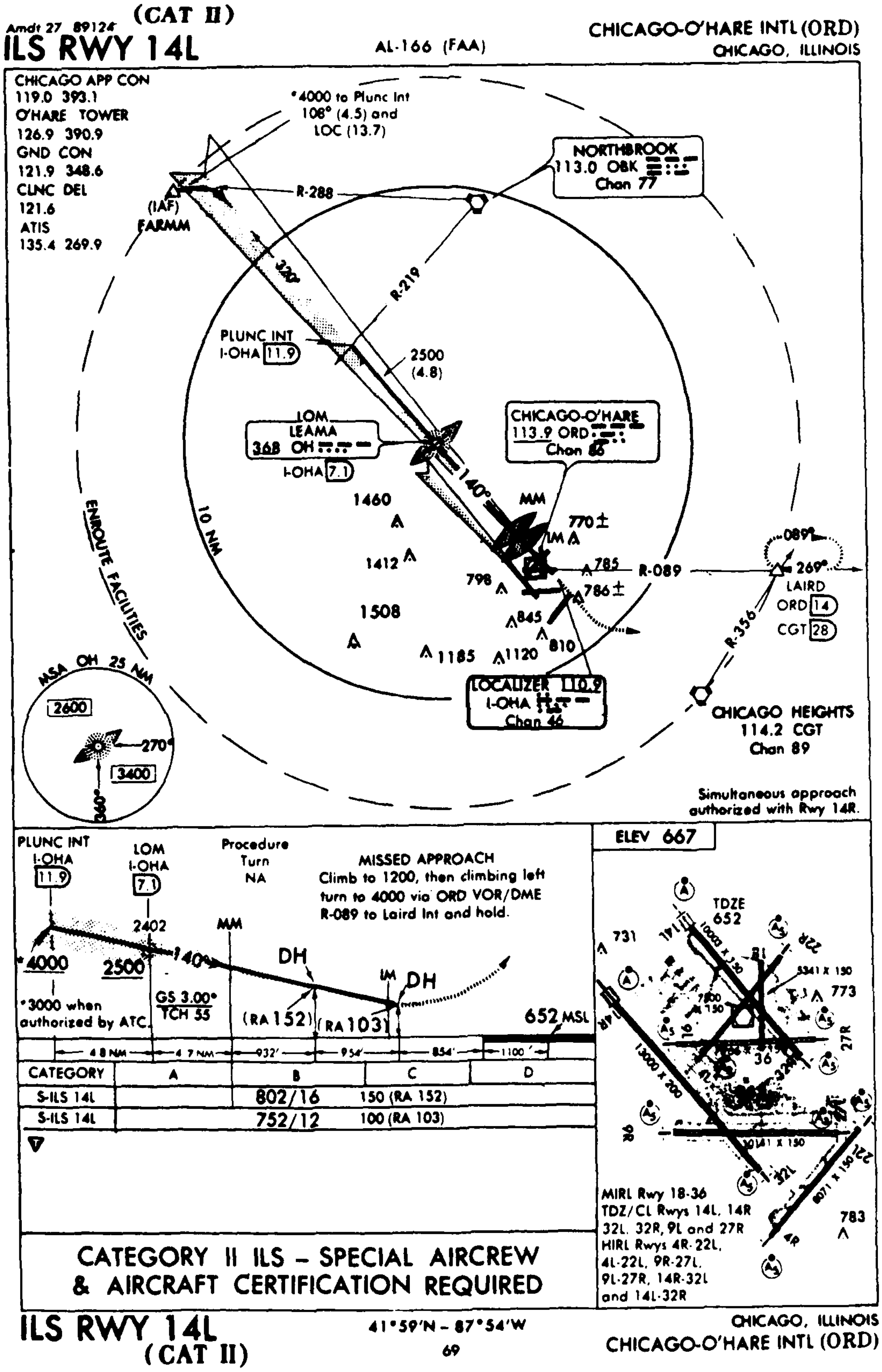
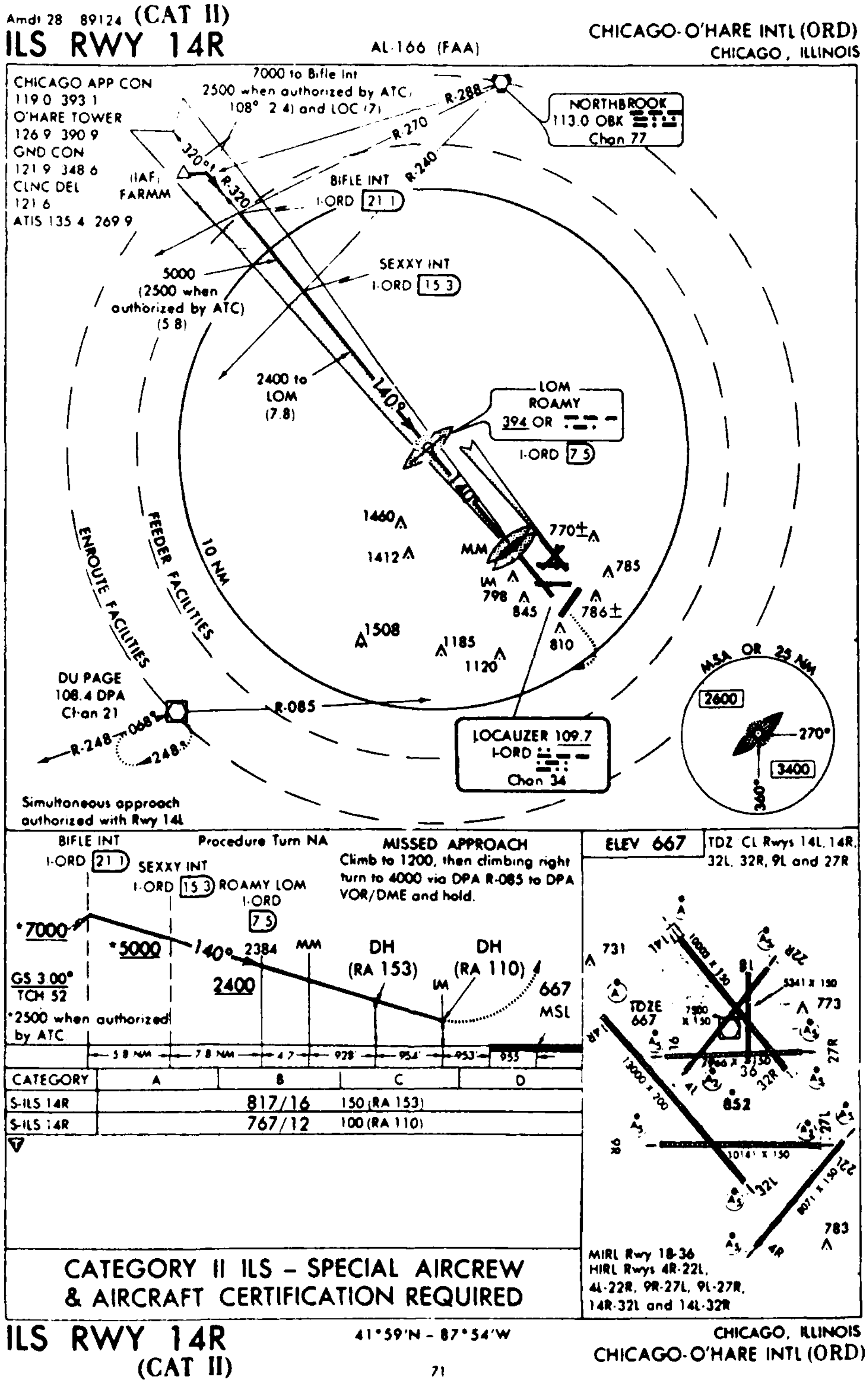


FIGURE 2.11 RUNWAY 14R ILS APPROACH CHART



CATEGORY	A	B	C	D
S-ILS 14L		802/16	150 (RA 152)	
S-ILS 14L		752/12	100 (RA 103)	

FIGURE 2.12 RUNWAY 14L ILS CATEGORY II APPROACH CHART



CATEGORY	A	B	C	D
S-ILS 14R		817/16 150 (RA 153)		
S-ILS 14R		767/12 100 (RA 110)		

FIGURE 2.13 RUNWAY 14R ILS CATEGORY II APPROACH CHART

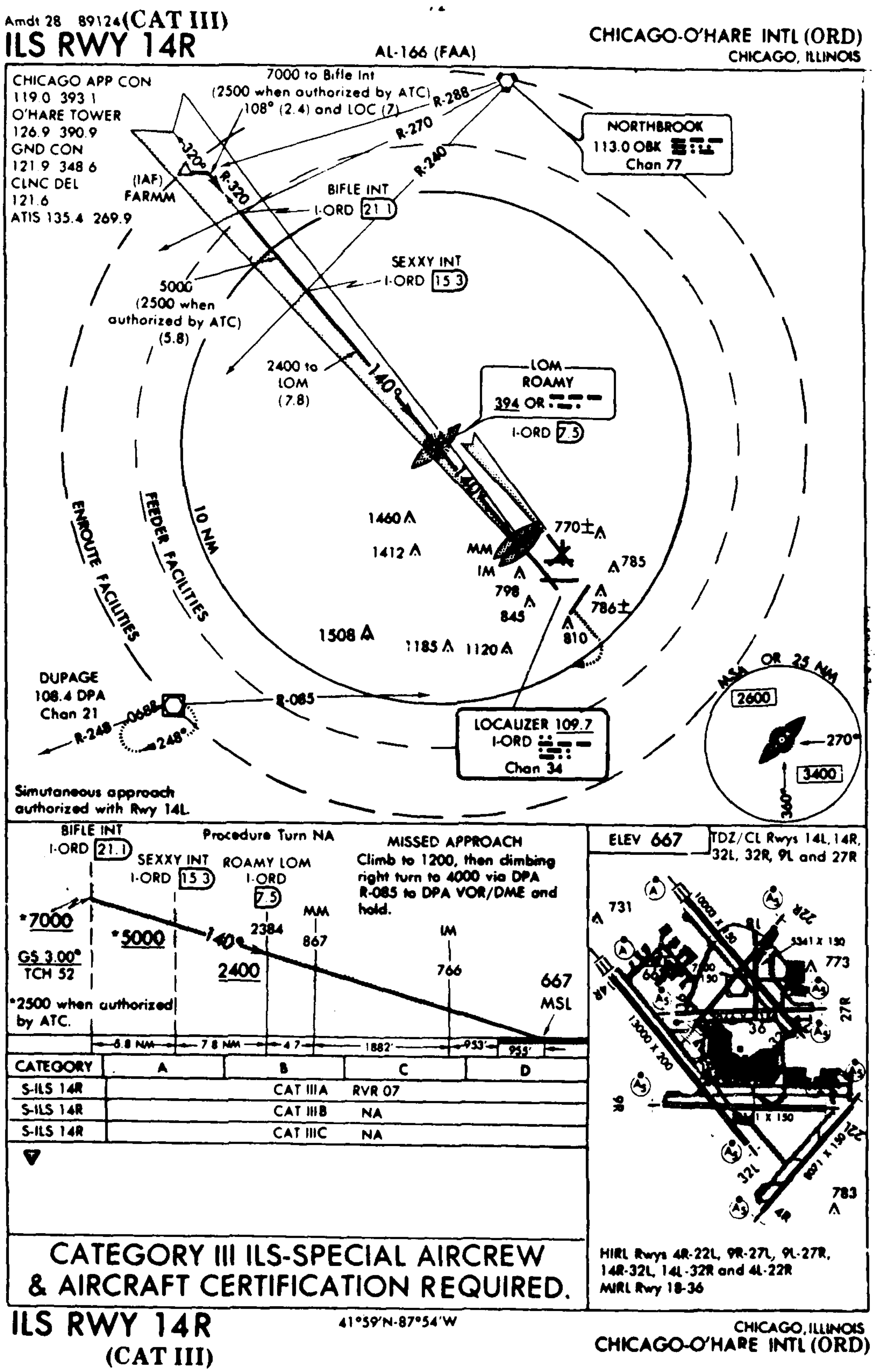


FIGURE 2.14 RUNWAY 14R ILS CATEGORY III APPROACH CHART

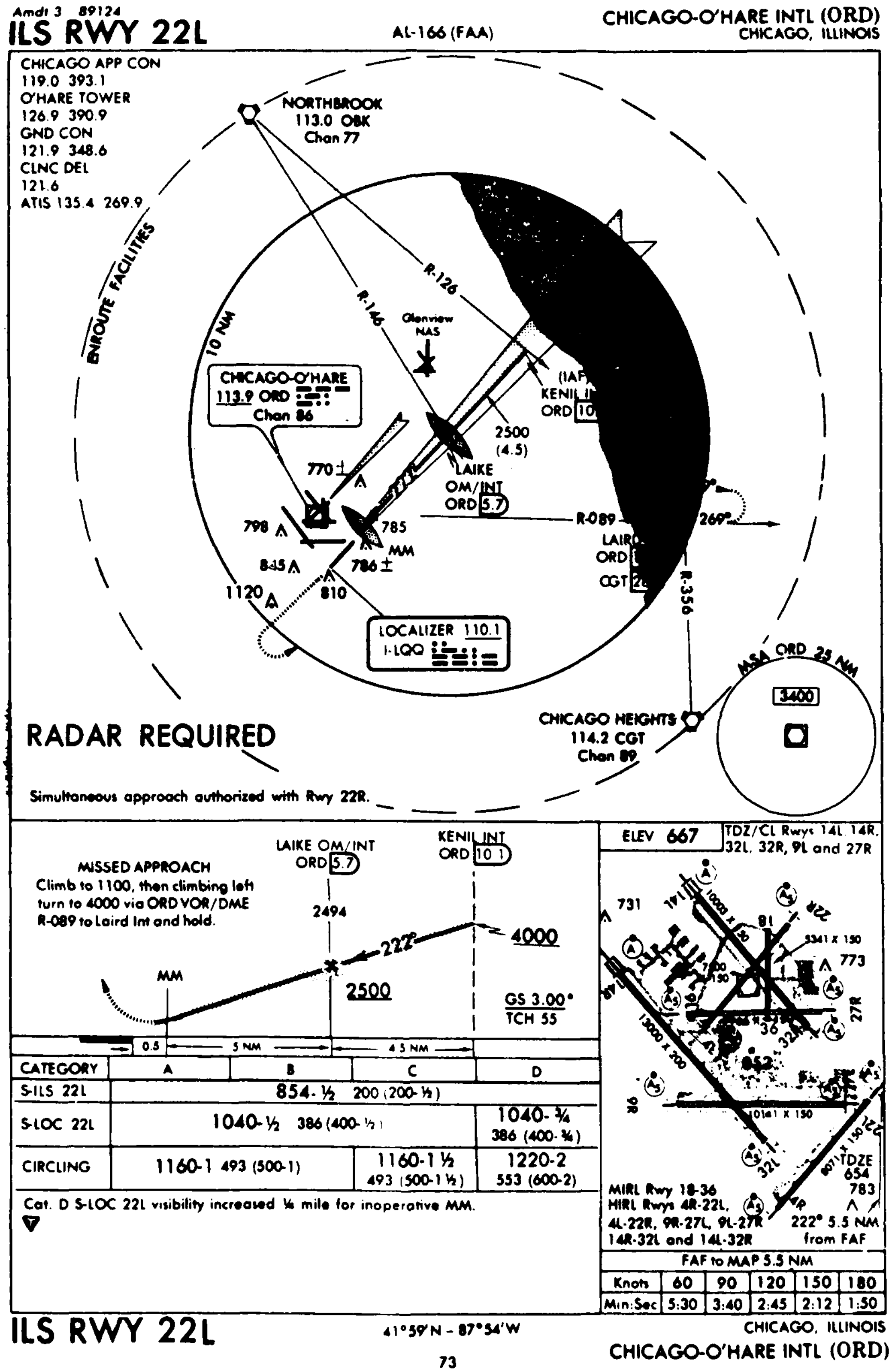
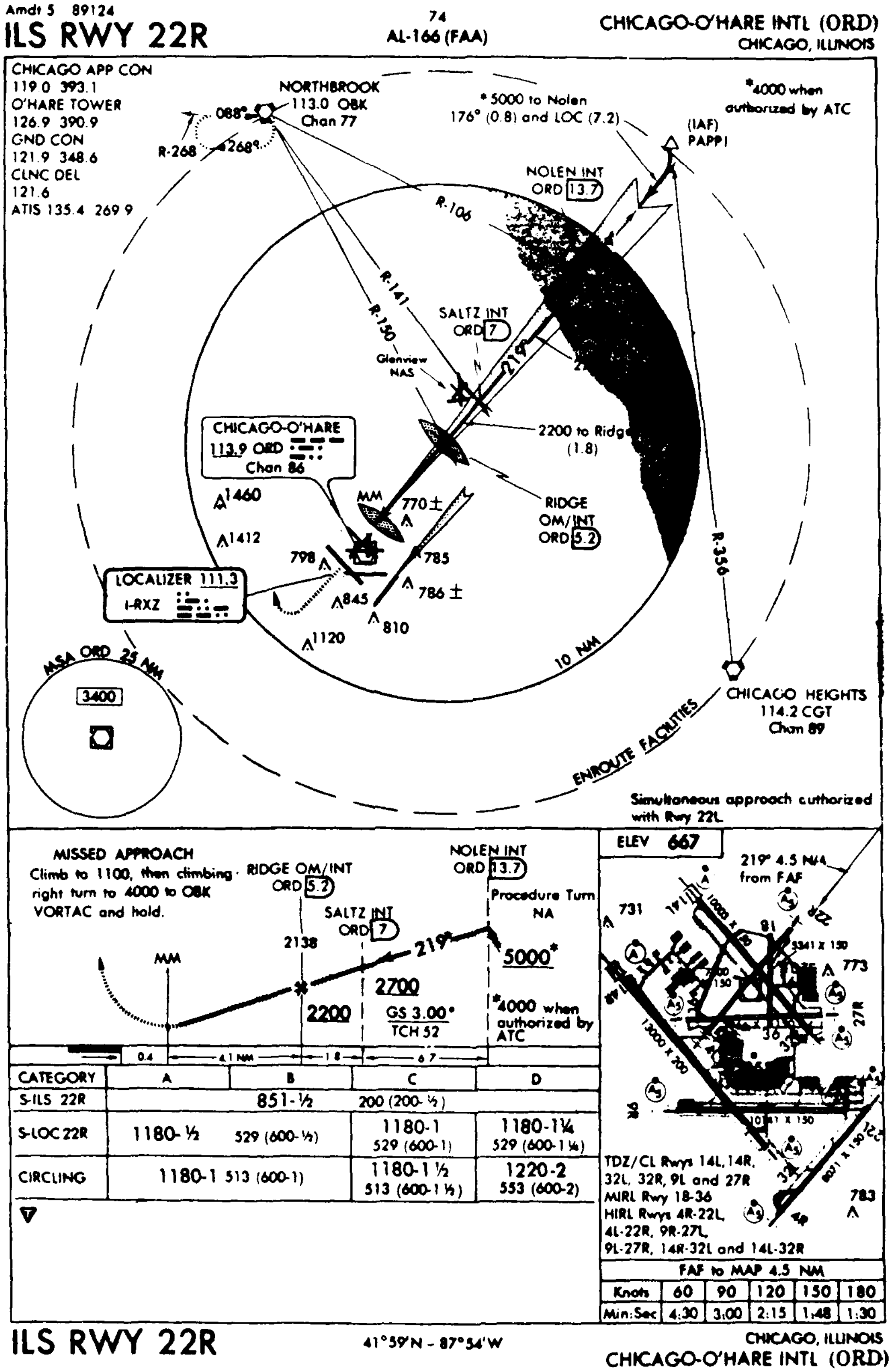


FIGURE 2.15 RUNWAY 22L ILS APPROACH CHART



CATEGORY	A	B	C	D
S-ILS 22R	851-½ 200 (200-½)			
S-LOC 22R	1180-½ 529 (600-½)		1180-1 529 (600-1)	1180-1¼ 529 (600-1¼)
CIRCLING	1180-1 513 (600-1)		1180-1½ 513 (600-1½)	1220-2 553 (600-2)

FAF to MAP 4.5 NM					
Knots	60	90	120	150	180
Min:Sec	4:30	3:00	2:15	1:48	1:30

FIGURE 2.16 RUNWAY 22R ILS APPROACH CHART

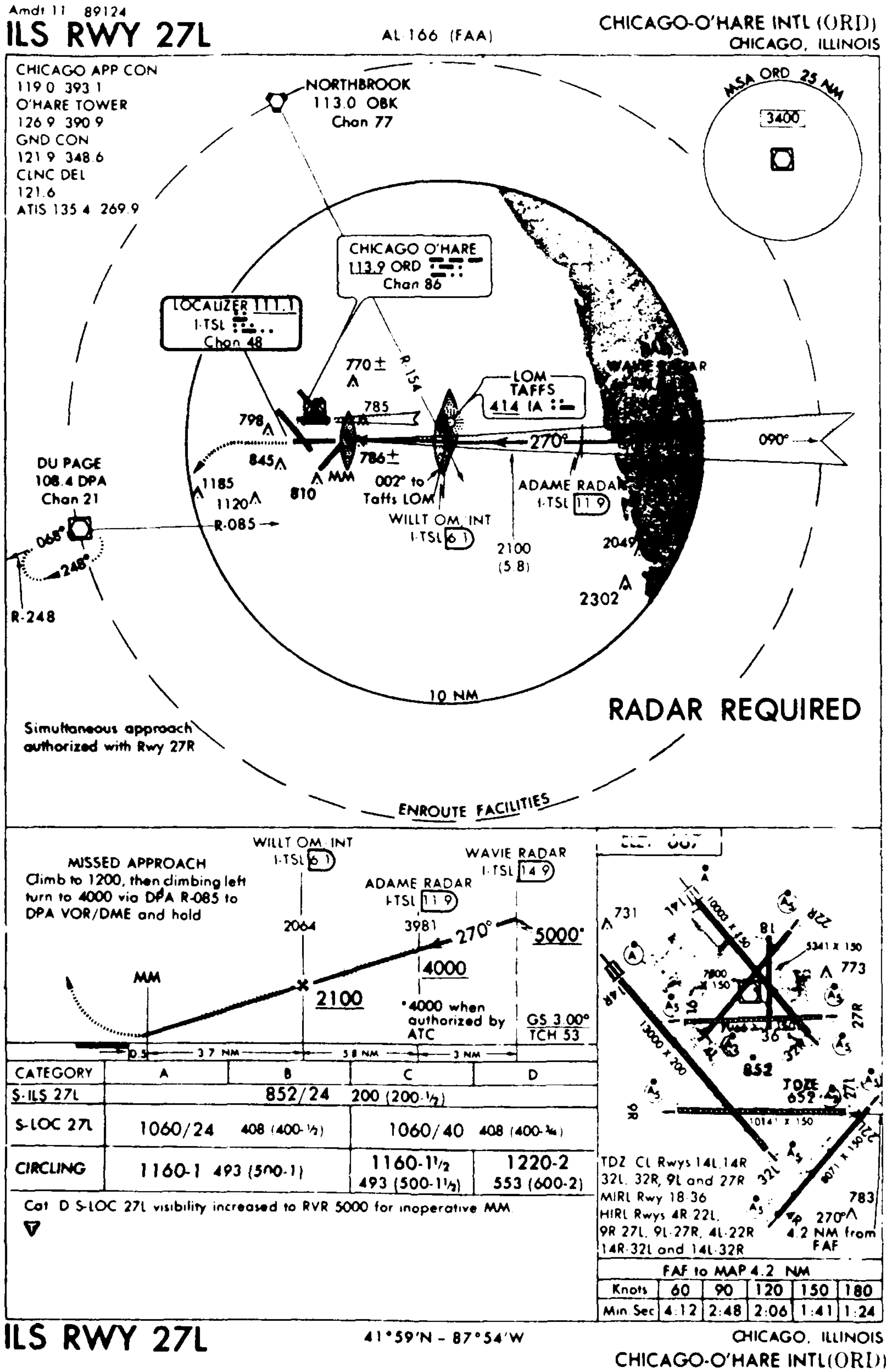


FIGURE 2.17 RUNWAY ILS APPROACH CHART

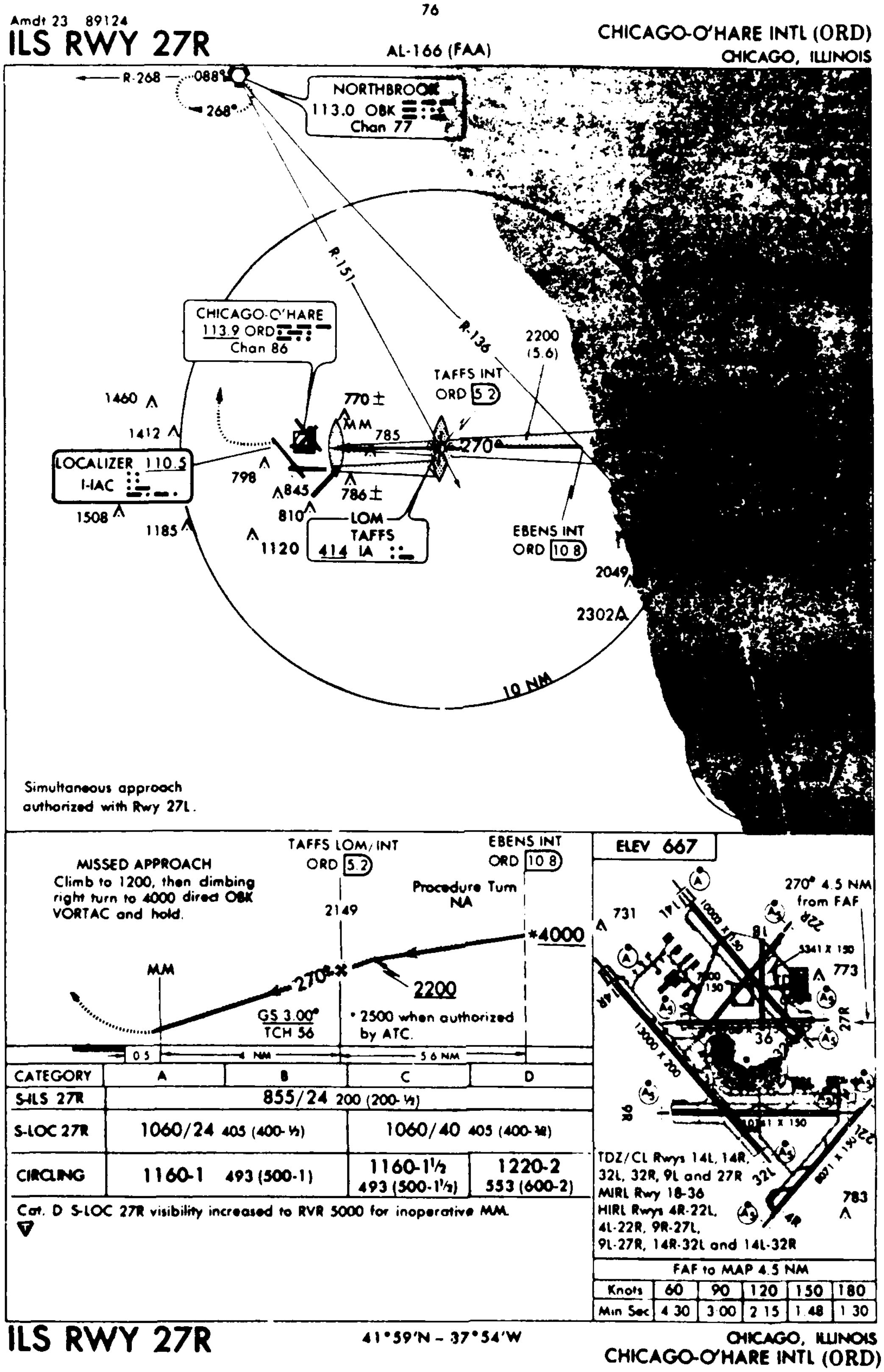


FIGURE 2.18 RUNWAY 27R ILS APPROACH CHART

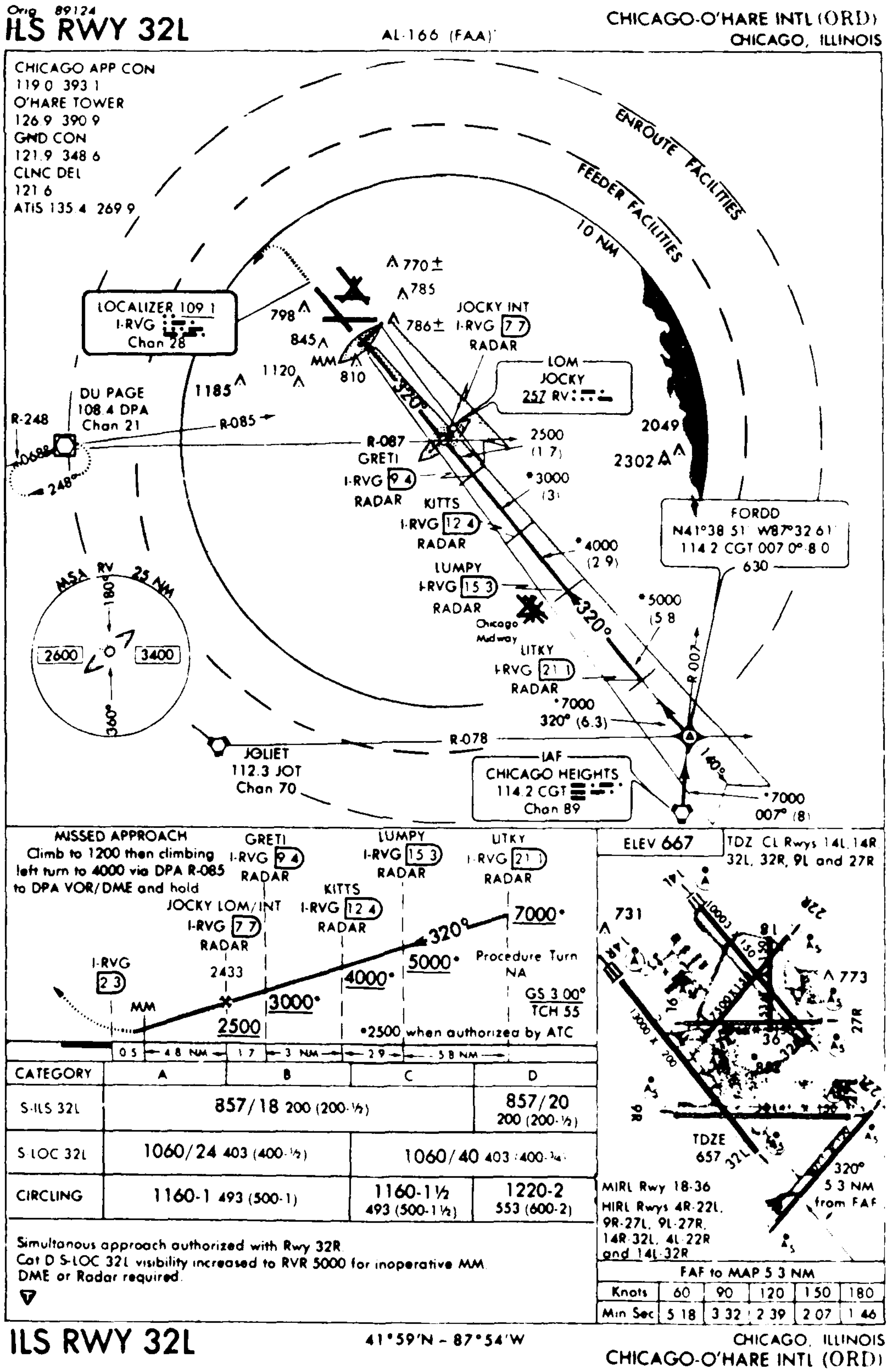


FIGURE 2.19 RUNWAY 32L ILS APPROACH CHART

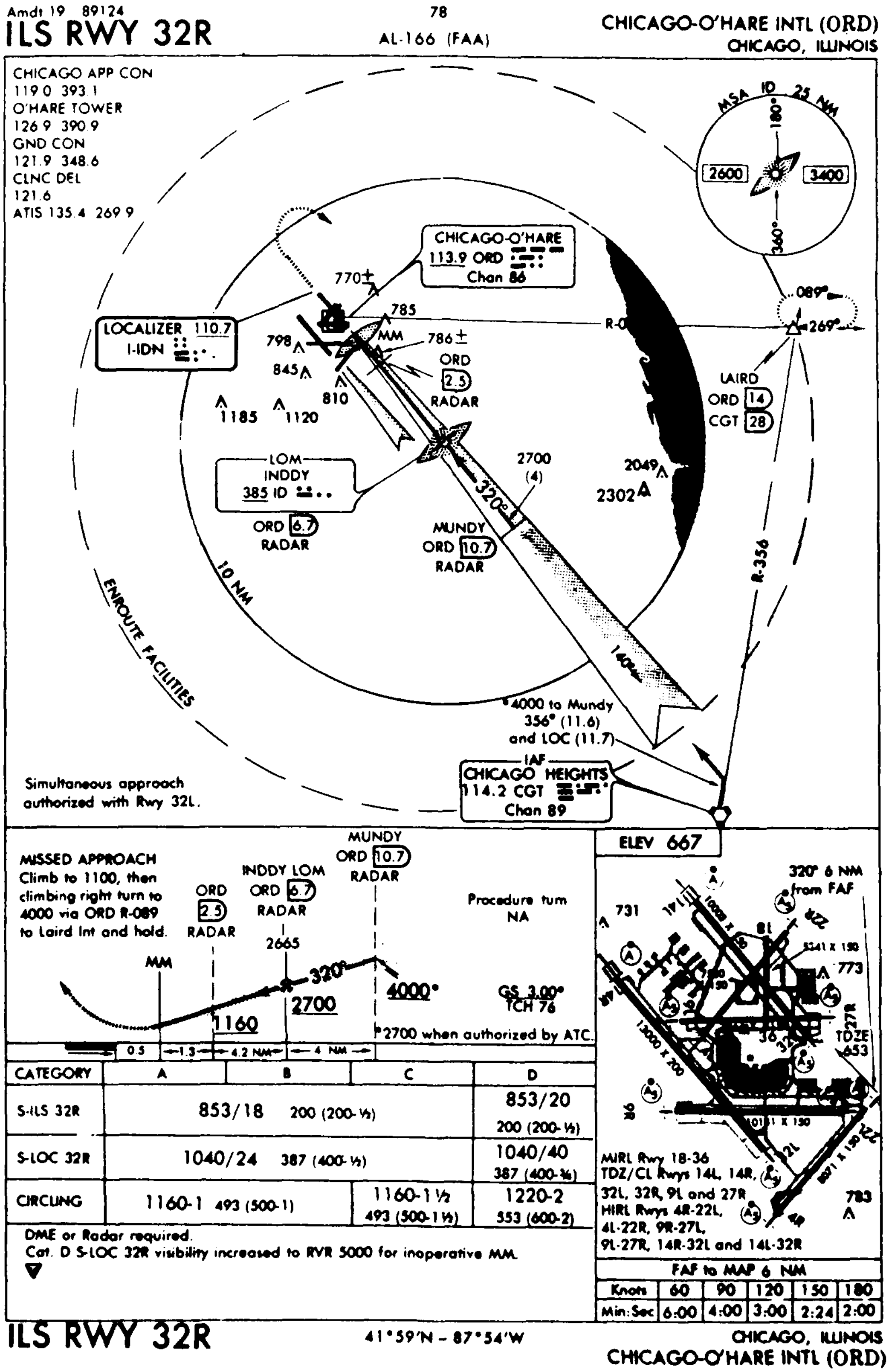


FIGURE 2.20 RUNWAY 32R ILS APPROACH CHART

second. Although PAR's are desirable from a performance standpoint for data collections such as this, unfortunately they are very expensive to lease, staff, and maintain. They also produce a tremendous volume of data, most of which change only a few feet from target report to target report.

Preliminary work was performed at the FAA Technical Center to determine the suitability of using existing airport surveillance radars (ASR's) to support the project. Tests were performed to compare position report accuracy of the ASR-4/air traffic control beacon interrogator (ATCBI)-3 and the ASR-8/ATCBI-5 class of surveillance radars against the Nike-Hercules PAR. The complete results of these tests are documented in two letter reports (references 15 and 16). Some of those tests are briefly discussed below.

2.2.1.1 Static Tests.

Static tests were performed both at the FAA Technical Center and at O'Hare using fixed targets. The ORD ASR-7 primary radar was evaluated using returns from the MTI reflector permanent echo (PE) located near the end of runway 14R (ORDFIXRT and ORDRTED data sets). Attempts were also made to isolate radar returns from other known area obstacles for which latitude/longitude coordinates were available (radio towers, buildings, etc.); however, these were very difficult to extract from the data. Three secondary radars were evaluated in the study. The O'Hare ORD ATCBI-4 was evaluated using target reports from: (a) an aircraft beacon transponder placed next to the runway 14R PE (ORDFIXBT dataset), and (b) the Downers Grove parrot (ORD-BI4 data set). The O'Hare QXM ATCBI-4 was evaluated using target reports from the QXM radar parrot (QXM-BI4 data set). Finally, the FAA Technical Center ATCBI-5 was evaluated using a parrot located on the Mizpah Fire Tower (A02011MZ and A02221MZ data sets). The effects of correlating a primary and a secondary radar report is shown in data set ORDFIXRB. The static test data is reprinted below from Thomas and Timoteo (reference 16).

It is significant to note that the quality of the correlated report (radar reinforced beacon) is superior to either the radar or beacon only report used alone. This is evident from table 2.2 by comparing the ORDFIXRB data set with either ORDFIXRT, ORDRTED, and ORDFIXBT. Although the standard deviation (sigma) of the azimuth data is only marginally smaller, the skewness (a measure of distribution symmetry) and kurtosis (index comparing length of distribution tail with a normal distribution) are significantly better. This can be seen in figures 2.21 through 2.24. Noise in either of the two independent radar systems tends to cancel a portion of the random measurement noise out.

2.2.1.2 Dynamic Tests

Two dynamic tests were conducted at the FAA Technical Center. Table 2.3 shows the range and azimuth error of the ASR-8/ATCBI-5 compared with the Nike Hercules PAR. Based on the azimuth error, these results indicate that for the Technical Center ARTS radars one can expect a 1 sigma random error of approximately 300 feet at 10 nmi.

12/23/87

RADAR

Radar Statistics for C:\FOXBASE\ORDFIXRT.DBF

Total number of samples is 533
Mean value of RANGE is 0.869 nmi.
Mean value of ACP count is 3781.97 (332.40°)
Standard Deviation of RANGE is 0.024 nmi.
Standard Deviation of ACP is 1.859
The Skewness of ACP is -2.969
The Kurtosis of ACP is 37.607
Range of ACP's is from 3760 to 3793

FIGURE 2.21 ORD ASR-7 MTI REFLECTOR RESULTS

12/23/87

EDITED RADAR

Radar Statistics for C:\FOXBASE\ORDRTED.DBF

Total number of samples is 531
Mean value of RANGE is 0.869 nmi.
Mean value of ACP count is 3781.99 (332.40°)
Standard Deviation of RANGE is 0.024 nmi.
Standard Deviation of ACP is 1.526
The Skewness of ACP is -0.522
The Kurtosis of ACP is 0.765
Range of ACP's is from 3775 to 3786

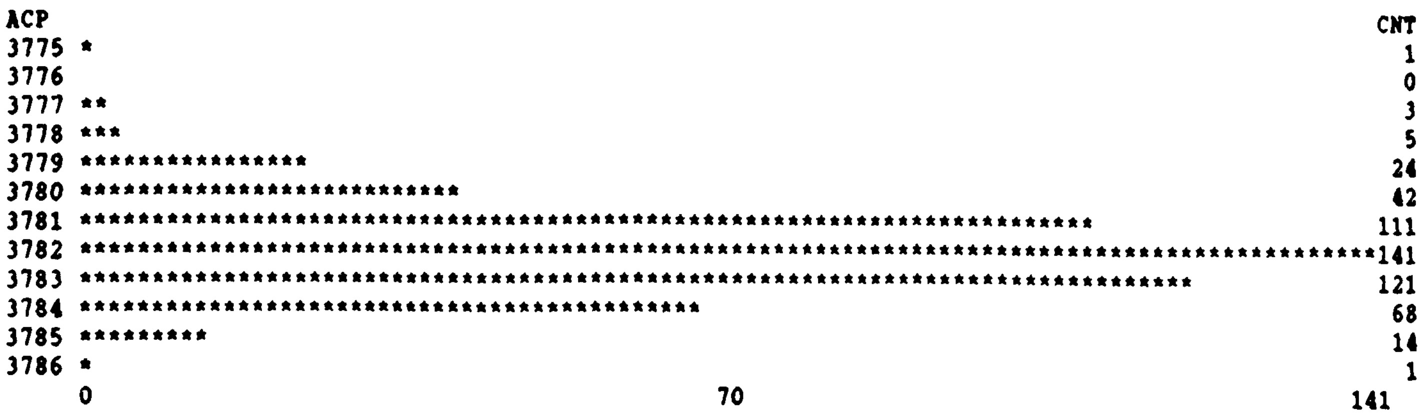


FIGURE 2.22 ORD EDITED ASR-7 MTI REFLECTOR RESULTS

12/23/87

BEACON

Radar Statistics for C:\FOXBASE\ORDFIXBT.DBF

```
Total number of samples is 329
Mean value of RANGE is 0.890 nmi.
Mean value of ACP count is 3779.92  (332.22°)
Standard Deviation of RANGE is 0.000 nmi.
Standard Deviation of ACP is 0.783
The Skewness of ACP is -0.323
The Kurtosis of ACP is 0.594
Range of ACP's is from 3777 to 3782
```

```
ACP                                                                                                         CNT
3777 *                                                                                                        2
3778 ****                                                                                                     7
3779 *********************************************                                                           78
3780 ****************************************************************************************************172
3781 ***************************************                                                                 67
3782 **                                                                                                       3
     0                                                86                                                172
```

FIGURE 2.23 ORD ATCBI-4 BEACON ONLY RESULTS

12/23/87

REINFORCED BEACON

Radar Statistics for C:\FOXBASE\ORDFIXRB.DBF

Total number of samples is 398
Mean value of RANGE is 0.871 nmi.
Mean value of ACP count is 3780.61 (332.28°)
Standard Deviation of RANGE is 0.005 nmi.
Standard Deviation of ACP is 0.742
The Skewness of ACP is 0.127
The Kurtosis of ACP is 0.161
Range of ACP's is from 3779 to 3783

```
ACP                                                                                                    CNT
3779 **********                                                                                          20
3780 *****************************************************************************                      153
3781 ***********************************************************************************************189
3782 ****************                                                                                    33
3783 *                                                                                                    3
     0                                              94                                               189
```

FIGURE 2.24 ORD ASR-7/ATCBI-4 RADAR REINFORCED BEACON RESULTS

TABLE 2.2. RADAR STATIC TESTS

Data set	******* Range *******			************* Azimuth in ACP's ************				
	Mean (nmi)	Calc (nmi)	Sigma (ft)	Mean	Calc	Sigma	Skew	Kurt
ORDFIXRT	0.869	0.838	146	3781.97	3806.55	1.859	-2.969	37.607
ORDRTED	0.869	0.838	146	3781.99	3806.55	1.526	- .522	.765
ORDFIXBT	0.890	0.838	0	3779.92	3806.55	.783	- .323	.594
ORDFIXRB	0.871	0.838	30	3780.61	3806.55	.742	.127	.161
ORD-BI4	38.284	38.146	30	2249.79	2259.89	1.196	- .761	8.043
QXM-BI4	47.010	47.125	12	56.44	90.59	1.067	- .479	2.005
A02011MZ	12.671	12.594	24	3354.55	3356.87	1.625	4.539	52.619
A02221MZ	12.594	12.594	18	3354.43	3356.87	1.397	-1.416	12.400

TABLE 2.3 FAA TECHNICAL CENTER ASR-8/ATCBI-5 ERROR STATISTICS

Run #	Sample Size	Range (ft) Mean	SD	Azimuth Mean	(ACPs/deg) SD	LATERAL DEVIATION MEAN	(ft) SD
2	60	234	172	.57/.05°	2.05/.18°	-20	115
3	64	275	179	.68/.06°	3.98/.35°	-31	161
4	58	270	171	.34/.03°	3.98/.35°	-53	131
5	61	291	184	.80/.07°	2.28/.20°	-64	115
6	57	264	171	.91/.08°	1.71/.15°	-37	93

Errors which occur in the primary radar reports are related mostly to the ability of the sensor receiver and processor (SRAP) to detect moving targets in ground clutter that is always present on radar video. Depending upon terrain, weather conditions, and aircraft range, reliably extracting a very weak reflected radar pulse can be a formidable task. Errors which occur in the secondary reports are related to the radar and SRAP's ability to receive ungarbled replies from an aircraft's transponder, and the transponder's ability to accurately detect and turn around a beacon's interrogation in 3 microseconds. The transponder's performance can vary with received signal strength which can only be determined by bench tests.

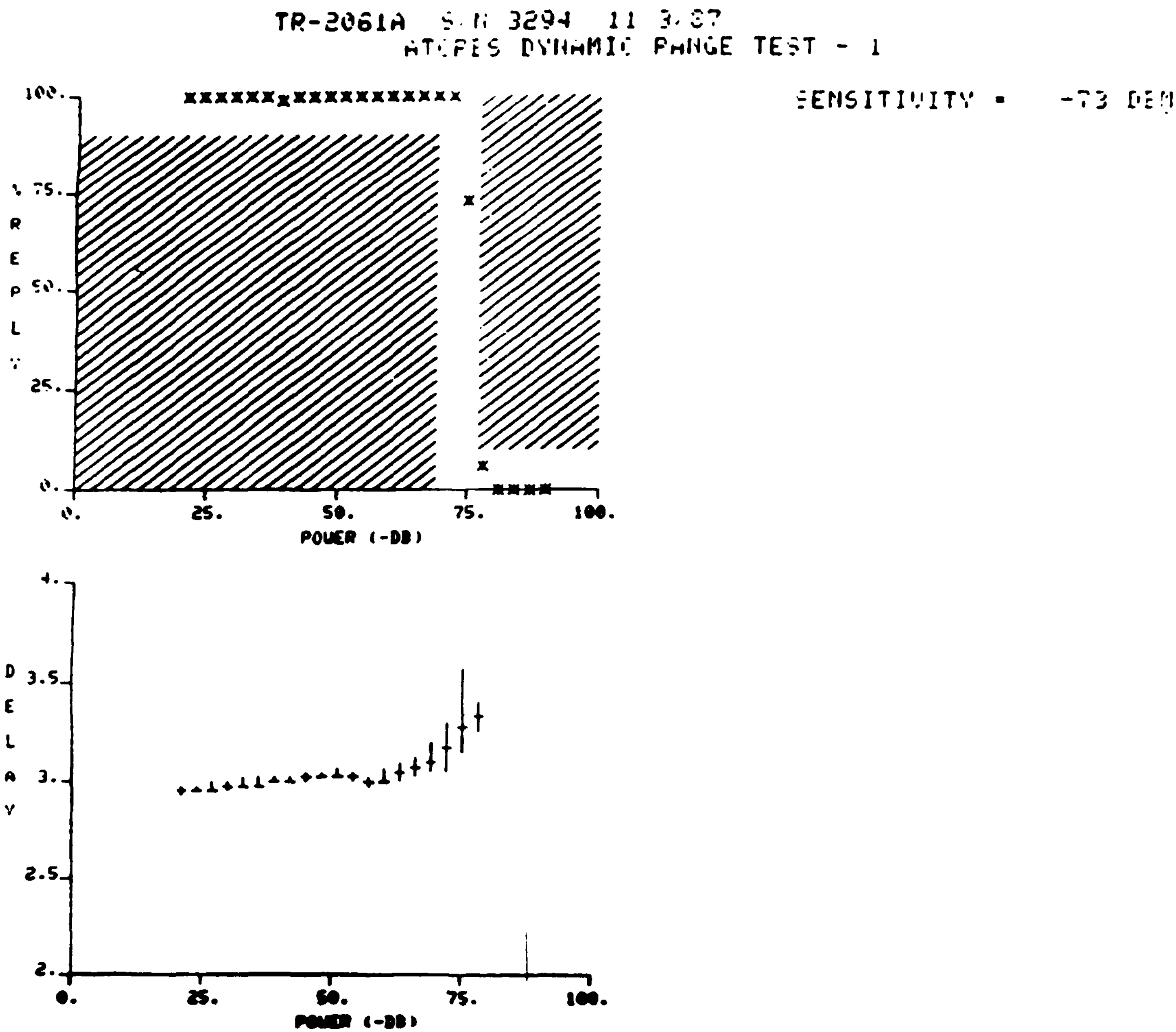


FIGURE 2.25 TRANSPONDER 1 BENCH TEST RESULTS (11/3/87)

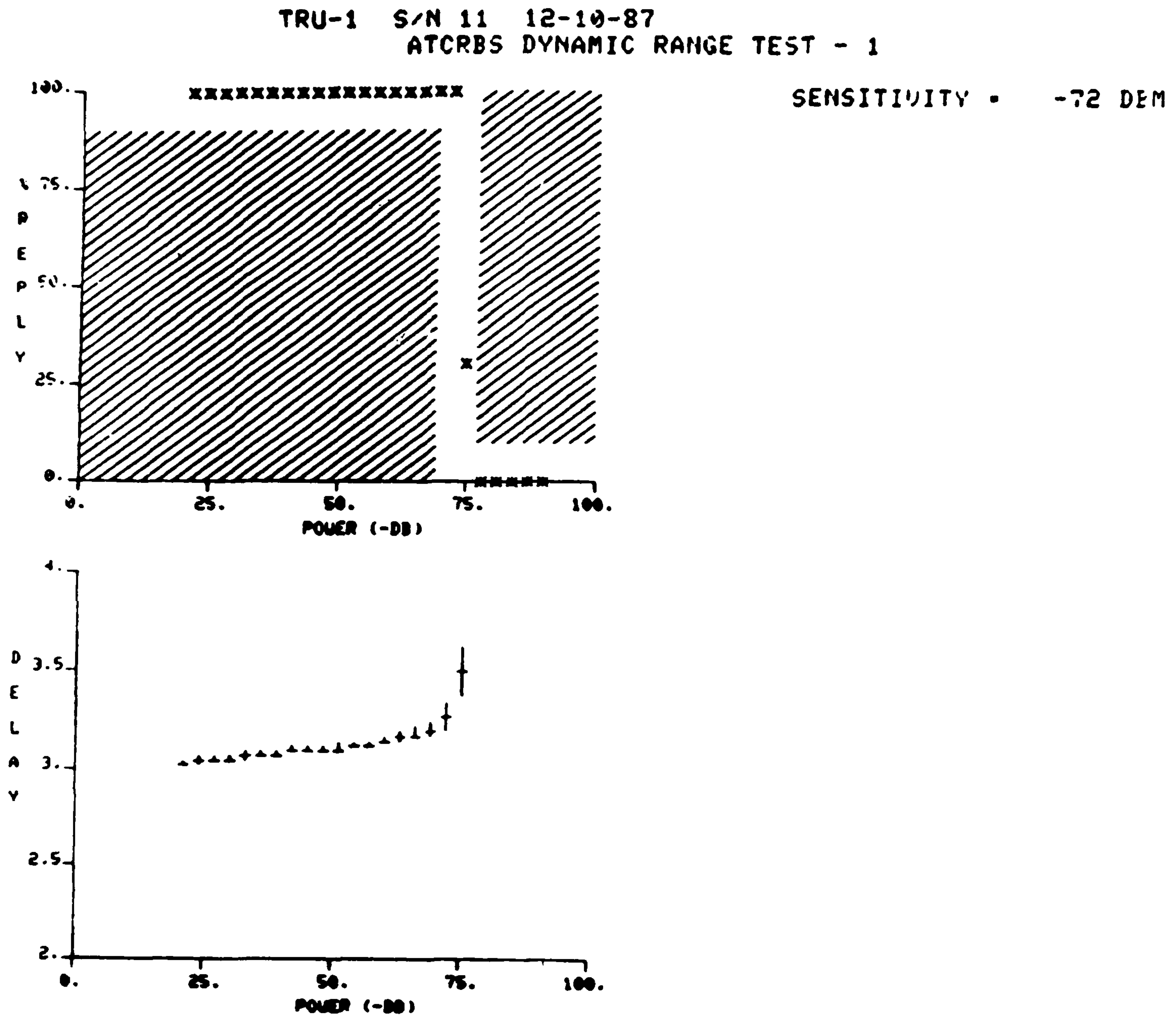


FIGURE 2.26 TRANSPONDER 1 BENCH TEST RESULTS (12/10/87)

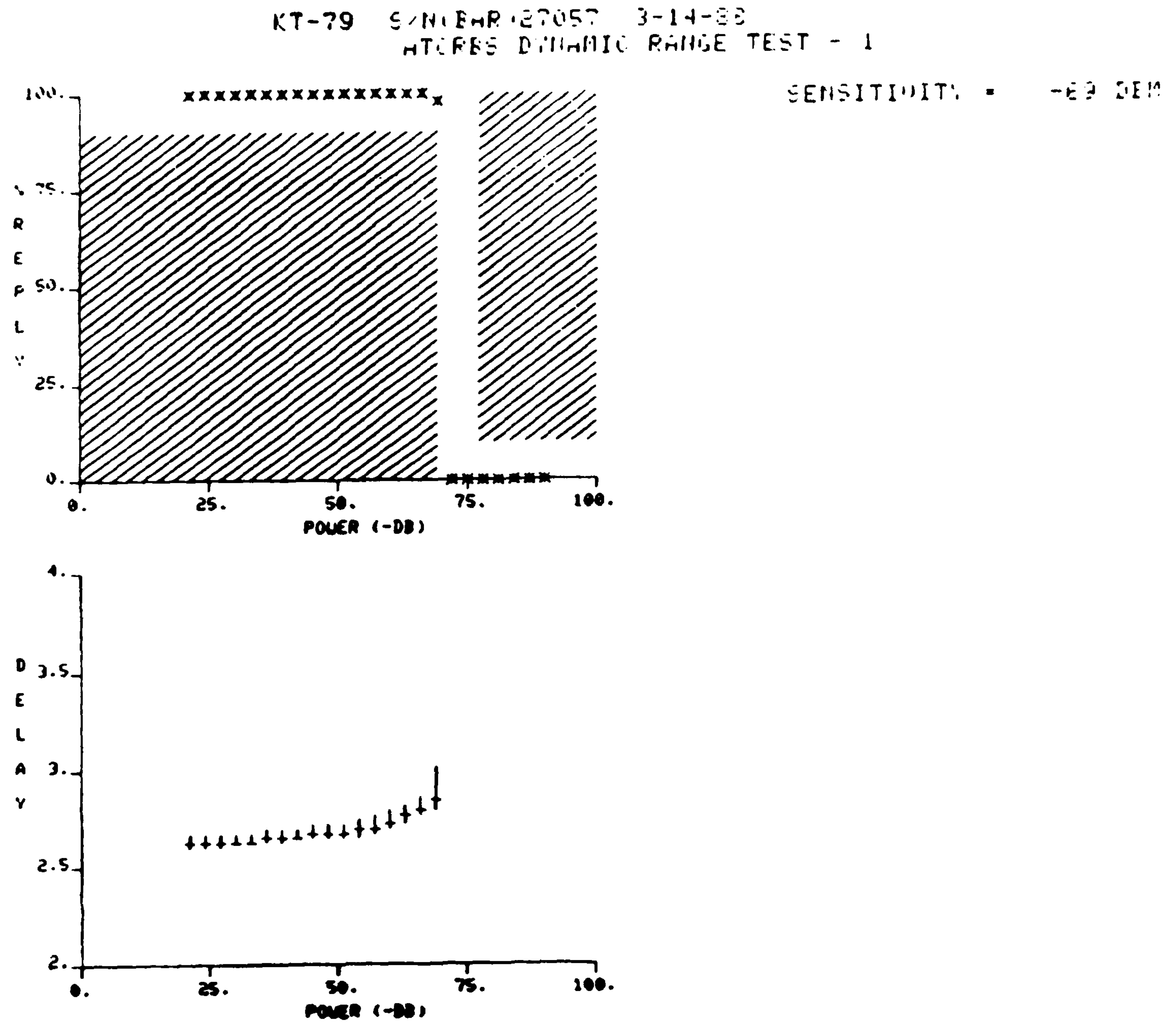


FIGURE 2.27 TRANSPONDER 2 BENCH TEST RESULTS (3/14/89)

2.2.1.3 Transponder Tests.

The last column of table 2.3 shows the error in the ARTS reported position along the axis perpendicular to the extended runway centerline (ideal ILS approach path). These results indicate that a 1 sigma error in the measure of lateral deviation from ILS centerline within 10 nmi of the radar antenna is approximately 130 feet.

Transponders are expected to receive and turnaround the beacon interrogation in 3.0 microseconds plus or minus 0.5 microseconds. At the specification limit, this turnaround tolerance can build in a plus or minus 245 foot range bias into the beacon range report. To determine the potential impact of this tolerance, three FAA transponders were subjected to a battery of bench tests, including the transponders used in the static and dynamic testing. The results of those tests are in figures 2.25 through 2.27.

All three were within acceptable limits. Two of the three transponders were close to the ideal 3.0 microseconds over most signal strengths; both showed increased delay (range would be reported "long") at weak signal strengths. The third was about 0.4 low (range would be reported about 200 feet "short"), again with slightly increased delay at weak signal strengths.

Since only a small sample size of transponders could be tested for this study, we are not able to make general or conclusive statements about the transponder performance of the whole aircraft population. We are aware, however, that the transponder can contribute a range bias that would be relatively constant within airport approaches. That bias could be larger than the expected random error of the measurement, and still be within tolerance.

2.2.1.4 Smoothing Techniques.

Aircraft often tend to exhibit a very low frequency sinusoid type oscillation about the ILS course when making runway approaches. This may be attributable to the dynamics of the aircraft control system, the large mass of the aircraft, the wind, and, when using manual control, the inability for the pilot to respond appropriately and accurately to visual cues. It is possible to obtain a better estimate of an aircraft's track by using a processing technique that takes into account target reports that occurred both before and after each processed point. This is possible since: (a) even at a relatively low radar update rate of 4.7 seconds, data sampling is always much higher than the Nyquist sampling rate for the frequencies of oscillations observed; (b) the velocity of the aircraft can change only a small amount from scan to scan; and (c) the transient response of an aircraft's lateral and vertical position from scan to scan is very slow.

One such smoothing technique was proposed by Eric Shank of Lincoln Laboratory (reference 17). This algorithm was of particular interest because it uses a number of standard techniques combined in a multistep process that exploits the strengths of each. The first step determines which points in the data set (in our case, the ARTS radar reports) that are clearly invalid in either position or time and, thus, are most likely to corrupt the estimated track. These "outlying" (low probability of validity) data points are then removed from the data set. The second step uses the "valid" data set in an attempt to differentiate between portions of the aircraft track that are essentially straight segments and those that are turns. The distinction between segment

types is important since linear curve fitting works best on straight segments while quadratic curve fitting works best on turning segments. The most difficult part of this task is to identify the point of transition from a straight to curved segment and vice versa. This algorithm uses a preliminary polynomial smoothing over seven data points to reduce noise in the raw data for reliable segment identification. These data are then passed through an alpha-beta tracker (similar to those used in the operational ATC software) to obtain speed, heading, and turn-rate estimates at each data point. The data are passed through an associated turn detection algorithm in the forward time direction to generate a turn radius estimate for each data point. Since this process is known to predict the <u>start</u> of a turn more reliably than the <u>end</u>, the data are then passed through the turn detection algorithm in reverse order to compensate for the inherently asymmetric process. The output of the second step is a list that specifies the straight and turning segments as well as the separating transition points. The third and final step uses the list generated in the second step to smooth the "valid" data obtained in the first step using a linear polynomial fit for straight segments or a quadratic fit for turning segments.

This algorithm was adapted and modified for better performance by project personnel for the personal computer to be used in the project work. A comparison was made between the raw dynamic data sets (see table 2.3) and the same data sets passed through the smoothing filter.

<u>2.2.2 Conclusions.</u>

These tests indicated that the FAA radars would provide a highly accurate track of aircraft if: (a) the SRAP were properly aligned using known PE's and beacon parrots, (b) periodic checks on SRAP alignment were made during the data collection activity, and (c) sufficient post processing was done to eliminate data artifacts and provide track smoothing techniques.

TABLE 2.4 ARTS LATERAL DEVIATION ERROR STATISTICS (RAW AND SMOOTHED)

Run #	Sample Size	Raw Lateral Deviation (ft) Mean	SD	Smoothed Lateral Deviation (ft) Mean	SD
2	60	-20	115	-20	70
3	64	-31	161	-29	82
4	58	-53	131	-25	69
5	61	-64	115	-42	59
6	57	-37	93	-42	57

2.2.3 ORD Radar.

Figure 2.1 shows the location of the ORD radar site with respect to the runways used for data collection (marked RDR on the chart). The radar site houses a standard FAA primary ASR-7 and secondary ATCBI-4 having a 4.7-second update rate. The analog radar videos and triggers are transmitted to the O'Hare Terminal Radar Control facility (TRACON) at the base of the O'Hare Tower via a Radar Microwave Link (RML-6) or alternately via a coax landline; no digital processing of the radar data is performed at the site.

At the TRACON, a SRAP extracts both primary and secondary targets from the respective radar videos. Three types of target reports are available from the SRAP (although not all simultaneously):

a. Radar only reports.
b. Beacon only reports.
c. Radar reinforced beacon reports.

The SRAP attempts to merge radar reports from the Radar Data Acquisition Subsystem (RDAS) with beacon reports from the Beacon Data Acquisition Subsystem (BDAS) that fall within the same range cell. When a radar and beacon report can be successfully correlated, a merged or radar reinforced beacon report is output. When this occurs, the individual radar only and beacon only reports are dropped from the output buffer and not output. Since the primary and secondary radars are independent processes using different measuring techniques, a high percentage of reinforced reports is indicative of good system performance and alignment.

The target reports, along with sector marks and alarm messages, are output digitally from the SRAP's Parallel Interface Module (PIM) to the ARTS IIIA system using one, two, or three 36-bit parallel words, depending on message type. Each message type has a specific format. The data collection equipment used the same interface ports used by the ARTS (see section 3 for further discussion).

2.2.3.1 ORD Radar Calibration and Alignment.

The following procedure was used at O'Hare to evaluate the alignment and some performance characteristics of the SRAP:

Both a fixed beacon transponder and an existing PE (MTI reflector) were used. The MTI reflector near runway 14R was chosen because it was by far the easiest to see on the radar display. Although easier for a trained eye, it was still rather difficult to discern which "smear" on the radar display was actually the MTI reflector. A set of active train tracks a thousand feet or so beyond the reflector added another dimension to this problem. The SRAP was able, however, to provide a return on the reflector.

The MTI reflector was physically located about 1100 feet beyond the end of the runway at the sixth light standard after the 14R ILS. This placed it exactly on the extended runway centerline. It is used at the tower to assure that the PE radar "target" and the map are in alignment, at least in the PVD visual presentation. The coordinates of this point (in latitude/ longitude) were provided by the Regional Office, and these were converted to range and azimuth to compare against the radar reports.

A project transponder which had been calibrated at the Technical Center was placed about 10 feet from the MTI reflector. A beacon code of 5110 was used. Testing was in IMC with light to moderate snow showers with temperatures in the low 30's. Data were collected on both the PE and transponder in three modes:

a. Radar reinforced beacon using the SRAP's RDAS and BDAS.
b. Beacon only using only the BDAS.
c. Radar only using only the RDAS.

Listings were produced from the offline Continuous Data Recording for this beacon code. Filtering was done by limiting selected range and azimuth in the radar only case. The data placed both the radar and beacon ranges slightly long with the beacon having the greater error. The beacon range was inherently more stable than the radar range, however. The azimuth was very close. Data collected on the ORD parrot transponder produced similar results.

Other tests were performed whereby the transponder was placed three light standards (about 300 feet) beyond the MTI reflector on the extended runway centerline. This was done to check the ability of the SRAP to correlate this intentionally misplaced "target," and to determine how the radar/beacon merging process in the SRAP calculated the radar reinforced beacon reported range and azimuth. Weather was VMC with temperatures in the upper 20's to low 30's. Data were collected again in all three modes. The results indicated that the primary/secondary report correlation decreased within the expected range and the resulting noncorrelated beacon reports fluctuated with a slightly greater standard deviation than the radar reinforced beacon reports.

Using these types of tests, the alignment of the SRAP was improved to a level acceptable for our work. Easier means to facilitate the testing and alignment process were developed and these are discussed in section 3.3.1 of this report.

3. DATA SOURCES AND DATA COLLECTION SYSTEM.

3.1 DATA COLLECTION SYSTEM SOURCES.

The data of paramount interest for the Chicago O'Hare data collection is the 3-dimensional position of aircraft flying instrument approaches to parallel runways. Aircraft position was determined from target replies provided by the ORD ASR-7 and ATCBI-4. Radar videos and triggers were provided to the project SRAP from a feed on the TRACON radar distribution amplifiers. The project used the exact same radar data used by the operational system. To minimize any potential impacts to the existing O'Hare ARTS, the project obtained a surplus SRAP from the FAA Depot in Oklahoma City for stand-alone use. This SRAP's analog front end and digital parameter settings were brought up to certification standards.

Data from the project SRAP was obtained directly from the PIM using two 50-conductor flat cables. A dual SRAP interface was designed and built by the project team to convert the SRAP logic levels and 36-bit output word format to a form usable by the PC.

In addition to the SRAP data, the following were also collected:

a. Arrival messages from the interfacility data processor (IDP)

b. Airport weather sensor data consisting of:

1. Runway Visual Range data (RVR).
2. Digital Altimeter Setting Indicator data (DASI).
3. Rotating Beam Ceilometer data (RBC).
4. Low Level Wind Shear Alert System data (LLWAS).

c. National Weather Service (NWS) reports.

d. Voice recordings of ATC/aircraft communications.

e. Accurate time source (WWVB broadcast station).

The ORD interfacility data were collected from the Interfacility Data System Microprocessor (IDSM). The IDSM provides information on flights in the National Airspace System (NAS). This information is transmitted to the ORD TRACON from the en route centers. For this data collection, only ORD arrival information was extracted and stored to disk; departures and over flight data were ignored.

The RVR provided visibility and runway lighting information for key runways. The DASI provided local digitized barometric pressure. The ceilometer produced cloud density and height information. The LLWAS provided average wind speeds and peak gusts at various field locations.

The ORD NWS meteorological reports were collected once a day via modem from the Kavouras, Inc. Meteorological Data Base Computer located at the Minneapolis International Airport. Reports were normally available on an hourly basis, with special reports given more frequently with rapidly changing weather conditions.

Voice recordings of all local control frequencies, the two approach control frequencies, and the Air Traffic Information Service (ATIS) channel were made on two 4-channel audio recorders. An accurate date and time-of-day stamp was an

integral part of each recorded channel. This would allow searches for specific portions of the recordings on a time basis.

The National Bureau of Standards (NBS) WWVB broadcast station located in Fort Collins, Colorado, was used as the data collection's reference time source. The time code used was IRIG-B. WWVB time was received and processed by a commercially available unit with a very accurate internal clock. This allowed maintaining a very stable reference at the site even for the few times that radio reception was poor. This time was used at the beginning of each data collection session to synchronize the PC internal real-time clock (DOS time). The DOS time was then used to time-stamp each of the SRAP reports actually recorded to disk.

A more detailed description of the contents of the individual data files collected is contained in appendix A.

3.2 DATA COLLECTION SYSTEM HARDWARE.

The data collection system was installed in the Chicago O'Hare TRACON. Figure 3.1 shows a block diagram of this system. It consisted of the following hardware:

a. One SRAP consisting of two RDAS and two BDAS subsystems

b. One IBM PC XT Computer System with companion Expansion Chassis

c. One Zenith Z-248 Computer System

d. One Interface Card Cage containing:

   1. Two SRAP to PC interface cards
   2. One Sensor Interface to PC interface card
   3. One RCMS to PC interface card
   4. One RVR interface card
   5. One DASI interface card
   6. One RBC interface card

e. One IDSM/Z-248 Interface Unit and cables

f. One Mountain Filesafe 7060 60 MB Tape Backup

g. One WWVB Time Code Receiver

h. Two VLR-466 Voice Logging Recorders

i. One American Power Conversion 1200VX Uninterruptible Power Source

The computers were standard IBM XT or AT compatible systems with a number of add-in cards. For the XT these included: (a) a 80286/80287 Turbo card with onboard memory cache for added processing power, (b) StarGate multiport serial coprocessor board to allow LLWAS serial data to be collected as a background process, (c) a 2 MB expanded memory board, and (d) a 2400 baud modem. For the Zenith AT compatible, these included: (a) 2.5 MB of extended memory, (b) Persyst multiport serial coprocessor board to collect the interfacility data, and (3) a 2400 baud modem. The custom boards made by project personnel are explained in more detail below.

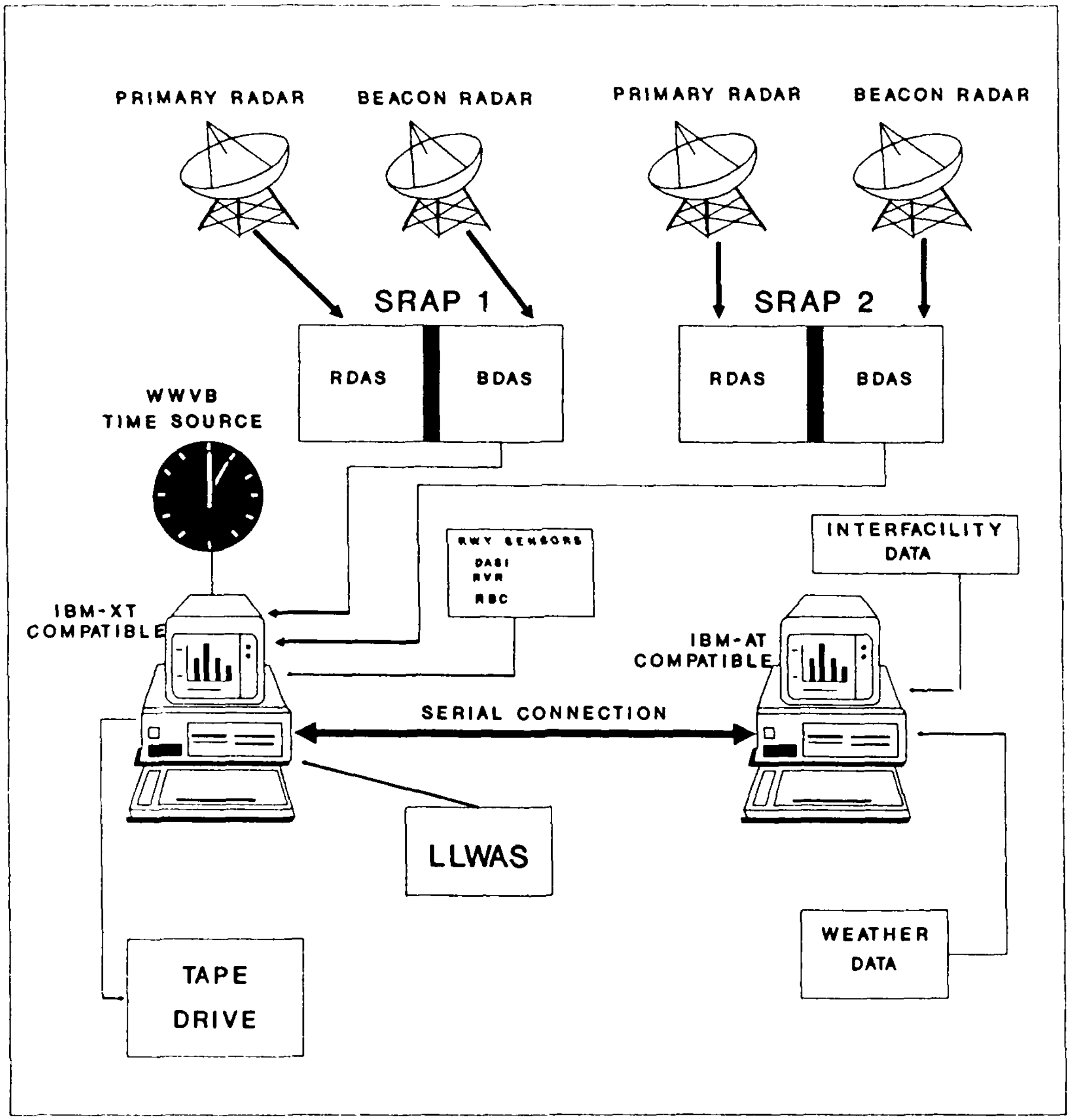


FIGURE 3.1 SRAP COLLECTION SYSTEM BLOCK DIAGRAM

3.2.1 SRAP/XT Interface.

FAA Technical Center personnel designed and fabricated a SRAP Interface and Control card set that permits a PC to connect to and receive the SRAP data. The interface supports all currently defined SRAP report types:

Report Type	Description
1	Radar only reports - uses ASR radar video
2	Beacon only/radar reinforced beacon reports - uses ATCBI or ATCBI/ASR radar videos
3	Alarms - reports SRAP processor errors
4	Sector mark - message output every 11.25° of radar scan
5	Weather - weather messages not available at ORD

The interface permits simultaneous collection of data from two separate RDAS/BDAS subsystems; the subsystems may be connected to the same or different radar sources. It provides the following preprocessing functions for each channel:

a. Automatic synchronization with the SRAP data by sector marks

b. Identification of each SRAP data report type

c. Filtering by sector for report types 1 and 2 above

d. Input, reformatting, and storage of a complete SRAP report

e. Hardware interrupt to XT to request report transfer

f. Transmission of report to XT via I/O channel on a byte basis

The interface incorporates azimuth filtering of the radar and beacon only/radar reinforced messages based on sector mark. Board-mounted DIP switches were used to select both a start and stop sector. These switches were set prior to each test to restrict collected sectors to those actually used by the aircraft during approach and landing. In this way the amount of unwanted data was minimized, thereby reducing the XT workload and the amount of collected data. The sector switches could be changed during a test without stopping collection. In this way, changing approach configurations could be accommodated while minimizing the amount of missed data.

3.3 DATA COLLECTION SYSTEM SOFTWARE.

The two computers were used to collect and store the data to hard disk. The IBM XT ran a program to collect, time-tag, and store the SRAP, RVR, RBC, DASI, and LLWAS data. The Zenith AT compatible ran two separate programs: (a) the first collected the interfacility arrival messages, and (b) the second collected and stored the NWS reports on a time scheduled basis.

3.3.1 XT Software.

The PC XT was connected to the SRAP and was used to execute programs to:

a. Determine the accuracy of PE and Parrot target reports

b. Determine precollection confidence and correlation

c. Collect the SRAP data during the collection sessions

3.3.1.1 SRAP Collection Software.

The data collection system software consists of foreground/background processes, and was written in 8088 Assembly language by the project team. To begin the data collection period, initialization of the system was accomplished by an interactive session with the system operator (figure 3.2) that defined the desired system configuration for that session. These options included:

a. Resetting the DOS time to WWVB time.

b. Range filtering of the collected targets with respect to the radar location (4, 8, 16, 32, or 64 miles).

c. Which sensors to be collected (RVR, DASI, CEIL, LLWAS).

d. SRAP(s) to be used (SRAP 1 and/or SRAP 2).

(Note: During the study, both SRAP's were connected only to the ORD radars; preliminary tests revealed that the alternate QXM radar was too far (about 15 nmi) from the airport for good coverage below 1500 feet.)

The runway sensor data has a relatively low data rate and can be handled via a background program within DUALSRAP that polls every 4 seconds to see if new data are present. SRAP data are available at a much higher data rate and must be handled by the foreground program using hardware interrupts. The interrupt service routine identifies the SRAP message as one of the five types previously defined (see above). The time of day is appended to each SRAP sector mark message (report type 4 of 3.2.1). Both the SRAP and runway sensor data are buffered and written to disk when the respective buffers become filled.

3.3.1.2 SRAP Pre-collection Test Software.

A data collection pretest program was used to verify that the SRAP data were error-free and contained arrivals on the parallel approaches under test. This process was actually a series of programs which collect, unpack, and report on the SRAP data. The process collected SRAP data until being terminated manually. The data were then automatically unpacked and analyzed producing a printed report showing for each SRAP being used:

a. The quantity of SRAP beacon only and radar reinforced reports collected per sector.

```
SRAP RANGE FILTER:  0 = 4 nmi      2 = 16 nmi      4 = 64 nmi
                    1 = 8 nmi      3 = 32 nmi


SRAP 0 OPERATING? [Y or N] Y
SELECT RANGE FILTER OPTION [0-4] 4
64 MILE RANGE FILTER CHOSEN? [Y or N] Y

SRAP 1 OPERATING? [Y or N] Y
SELECT RANGE FILTER OPTION [0-4] 3
32 MILE RANGE FILTER CHOSEN? [Y or N] Y

RCMS OPERATING? [Y or N] Y

LWAS OPERATING? [Y or N] Y

ENTER SOURCE TO BE USED FOR TIME STAMPING, DOS/WWVB (D/W) W


THE FOLLOWING DATA SOURCES ARE ACTIVE FOR THIS RUN:
SRAP0: 64 nmi     SRAP1: 32 nmi     RCMS       LLWAS      Time= WWVB

CONFIGURATION SATISFACTORY? [Y or N]                "<Ctrl>C" to Terminate
```

FIGURE 3.2 TYPICAL DUALSRAP SETUP SCREEN

b. A sorted listing of collected beacon codes showing the number of scans and the highest and lowest Mode C altitudes for each.

c. A listing of all SRAP alarms produced during the test.
The following criteria was used to determine from the above reports whether the system was functioning properly:

a. Radar reinforcement for the selected sectors was 50 percent or greater

b. The test targets were well represented in the data, and were recorded from the start of their approach through touchdown

3.3.1.3 SRAP Quality Test Software.

The SRAP Quality Test Software was used periodically to assess the percentage of missed scans, to determine the reliability of the position reports coming from the SRAP, and to determine the SRAP alignment. It is a series of programs that collect, unpack, analyze, and produce a statistical report on the quantity and quality of the SRAP beacon only/radar reinforced beacon reports. The report (figure 3.3) consisted of:

a. The mean and standard deviation of the test target range (the ORD Downer's Grove Parrot transponder).

b. The mean and standard deviation of the test target azimuth.

c. A plot of the distribution of test target azimuthal reports.

3.3.2 Zenith AT compatible Collection Software.

Interfacility data were collected by the Zenith Z-248 AT-compatible via a Fortran program leased from Landrum and Brown (reference 18). The interfacility data collection program was normally started automatically at 5:00 a.m., but could be started manually. This program had to be started at least 1 hour before a data collection session because interfacility messages for arrivals are sometimes transmitted to the TRACON up to an hour before the arrival occurs. The program extracted only arrival messages and stored them to disk.

The NWS data were collected via a communications program provided by Kavouras Inc. (reference 19). This program was run once daily to obtain a historical record of the last 30 weather reports available for ORD.

The interfacility and weather collection programs were normally run automatically via an appointment scheduling terminate and stay resident (TSR) program (reference 20). At 5:00 a.m. the scheduler would start an Extended Batch Language (reference 21) program which performed the following:

a. Start the ARTS IDentification Data Acquisition System (ID-DAS) (reference 19) interfacility data collection program. This program collected interfacility data throughout the day and was automatically terminated at 10:00 p.m.

```
15:23:16                                                                  03/23/89

                        Radar Statistics using F:\ORD1275.DBF
----------------------------------------------------------------------------------

            >>> SRAP 1 PARROT TEST   3-23-89    13:30  ---> 14:21 <<<

                 Total number of samples is 628
                 Mean value of RANGE is 38.172 nmi (231704 ft)
                 Mean value of ACP count is 2252.10 (197.94 deg)
                 Standard Deviation of RANGE is 0.002 nmi (10.0 ft)
                 Standard Deviation of ACP is 1.420  (0.125 deg/2.18 mr)
                      or 504.7 ft @ 38.172 nmi
                 The Skewness of ACP is 0.813
                 The Kurtosis of ACP is 8.211
                 Range of ACP's is from 2245 to 2263
                      or 197.31 to 198.90 deg


ACP                                                                            CNT
2245                                                                             1
2246                                                                             0
2247                                                                             1
2248 *                                                                           3
2249 ****                                                                       11
2250 **************                                                             43
2251 *******************************************                               128
2252 *************************************************************************218
2253 ***************************************************                       153
2254 *****************                                                          51
2255 *****                                                                      14
2256 *                                                                           2
2257                                                                             0
2258                                                                             0
2259                                                                             1
2260                                                                             1
2261                                                                             0
2262                                                                             0
2263                                                                             1
     +-----------------------------------|------------------------------------+
     0                                  109                                  218
```

FIGURE 3.3 SRAP QUALITY TEST REPORT

b. After ID-DAS termination, start the PC-Weather program (PCWX) to log onto the Kavouras network and download the requested weather reports to disk.

(Note: The ID-DAS program could be manually terminated prior to 10:00 p.m. by striking the ESC key. The PCWX program would still be automatically started after ID-DAS termination.)

3.3.3 Miscellaneous Software.

Other support software included routines:

a. To transfer the interfacility and weather data from the Z-248 to the XT.

b. To backup the data to tape.

c. To perform error-detection.

Once all data had been collected and transferred to the XT, it was stored daily on a magnetic tape cartridge. The data were then brought back to the Technical Center for further data reduction and analysis.

4. ANALYSIS.

The raw data were processed to reduce it to a form suitable for analysis. This reduction process is described in appendix B. Appendix A describes the data files generated in both the collection and reduction processes.

4.1 GOAL OF ANALYSIS.

As stated previously, the primary objective is to characterize the precision with which today's aircraft fly the ILS during simultaneous operations in IMC. A second objective is to specifically determine the percentage of these approaches contained within a hypothetical 550-foot NOZ. Simply stated, these objectives will disclose how well today's population of aircraft adhere to the extended runway centerline when flying simultaneous ILS approaches.

A third objective is to perform a risk analysis of simultaneous IMC operations on closely spaced parallel runways where radar monitoring is employed. This required the adaptation and modification of existing models that analyze risk, but do not specifically address the simultaneous approach situation. The scope of this report does not cover this objective; the reader is referred to "A Stochastic Model for Parallel Runway Separation Analysis" (reference 11) for a detailed treatise concerning the risk analysis.

4.1.1 Simultaneous Approaches at ORD.

Figure 4.1 shows two of the vertical profiles collected, one for runway 27L and the other for 27R. They are typical of the majority of sampled ILS flight paths for the three sets of parallel runways at O'Hare. The approach controller will vector the aircraft onto the approach at no more than a 30° angle relative to the localizer and at a sufficient distance to allow for localizer stabilization before glide slope intercept. It can be seen that during simultaneous operations aircraft on adjacent approaches are turned-on with 1000 feet of vertical separation. This separation does not decrease until the higher aircraft intercepts the glide slope. For the approaches depicted in figure 4.1, vertical separation begins to be lost about 12 miles before touchdown. This separation does not approach zero until the lower aircraft intercepts its glide slope, which is about 10 miles from touchdown. Thus, both aircraft should be stabilized on their respective localizers by 10 to 10.5 miles from touchdown.

The classic simultaneous operations are conducted in the above manner. In reality, however, depending on traffic volume and incidence of missed approaches, there was a significant proportion of aircraft that were turned-on too close to touchdown to be stabilized by 10.5 miles before touchdown. At O'Hare, about 16 percent of the sample collected were turned-on too close to threshold to allow for localizer stabilization before glide slope interception. This is not to say that these aircraft were at any risk of collision with aircraft on the adjacent parallel approach. In fact, these short turn-ons occurred when there were lulls in approaching traffic or when ATC was changing runway configuration. During these times, ATC insured that at least three miles radar separation occurred at turn-on.

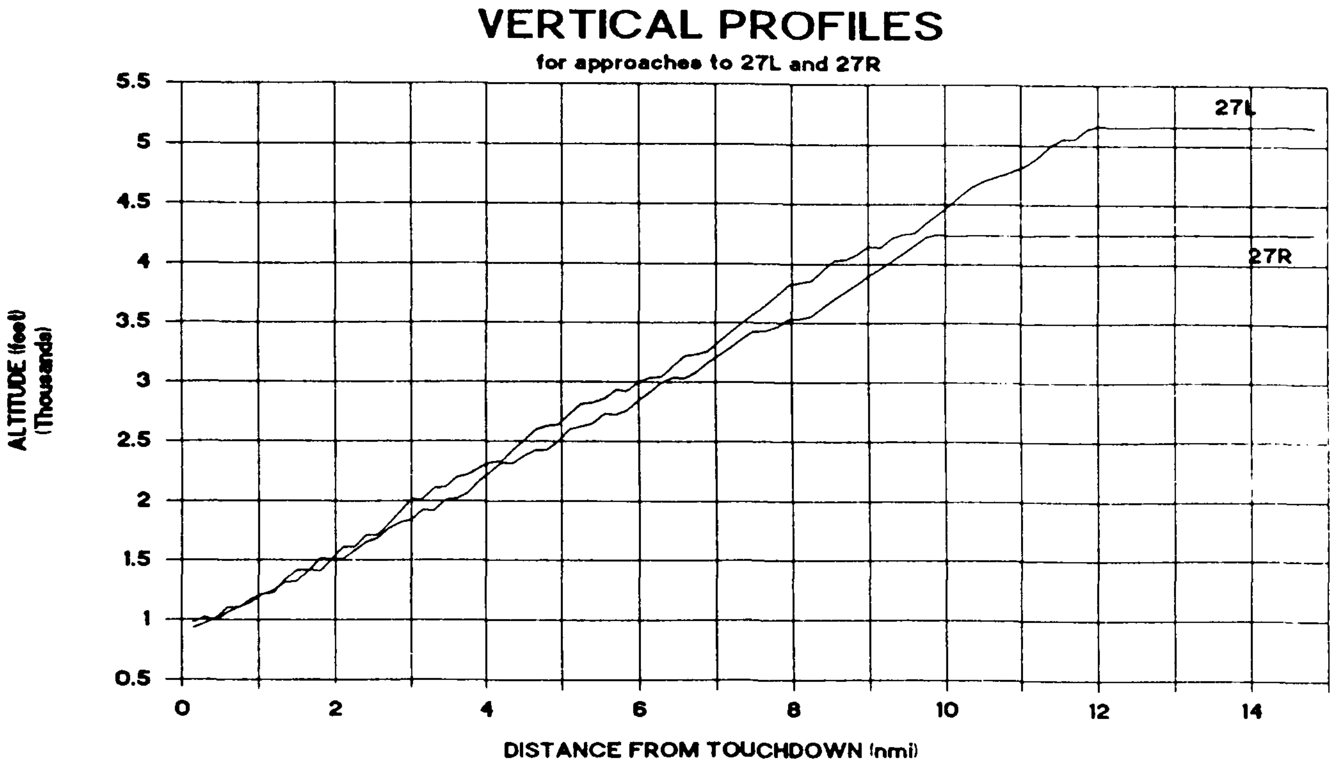


FIGURE 4.1 TYPICAL SIMULTANEOUS ILS APPROACHES

IN THE VERTICAL PLANE

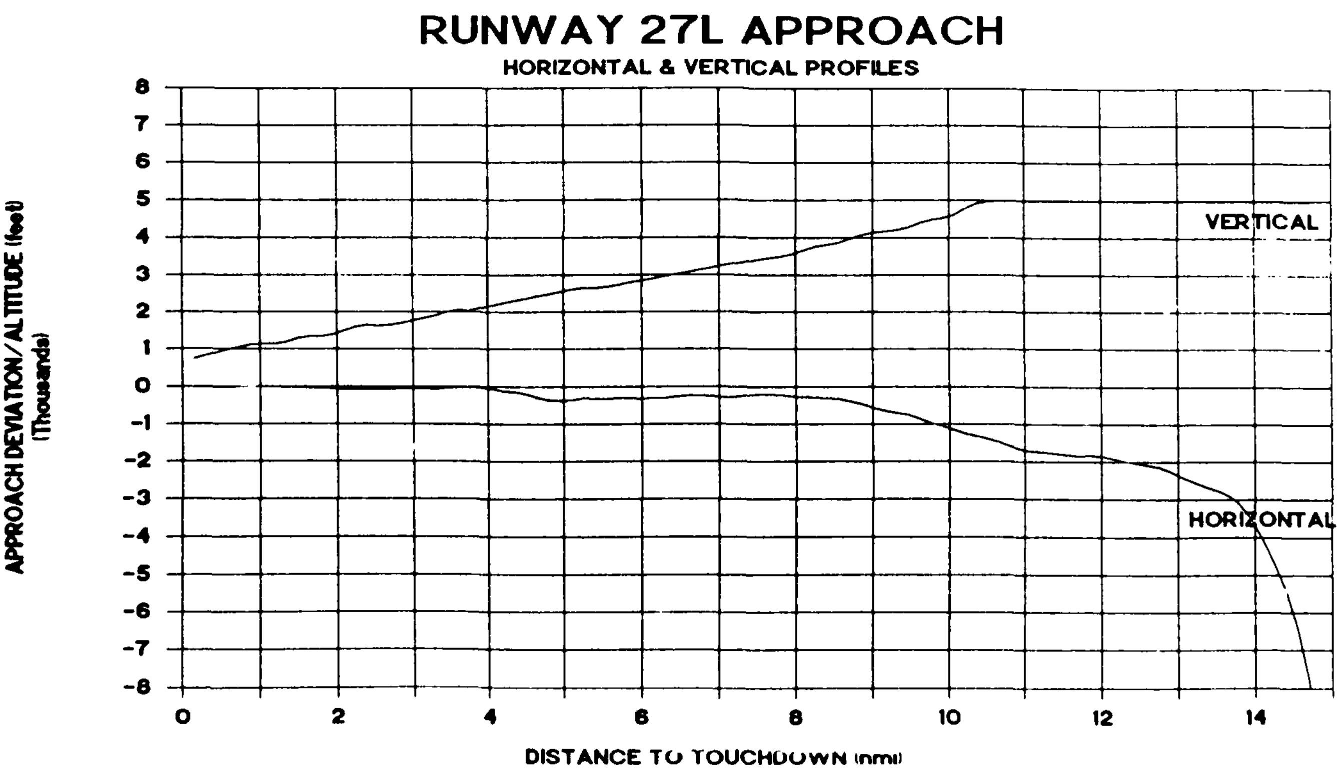


FIGURE 4.2 ASYMPTOTIC APPROACH IN THE HORIZONTAL PLANE

Typically, aircraft acquire the ILS in one of three ways:

a. The aircraft may asymptotically acquire the centerline with no overshoot whatsoever (figure 4.2).

b. It may cross the centerline with a minimum of overshoot (figure 4.3).

c. It may cross the centerline with a large overshoot, then exhibit subsequent oscillations about the centerline before stabilizing on the localizer (figure 4.4).

In all cases there is virtually no danger of conflict with an aircraft on the adjacent parallel approach since the aircraft are separated in the vertical plane by 1000 feet or in the horizontal plane by at least 3 miles during turn-on and subsequent localizer stabilization.

4.1.2 The Views.

It was necessary to edit the data for each recorded track so that the stable localizer flightpath, henceforth referred to as "navigation," could be analyzed independently of the turn-on and initial overshoot segments. Since no standard method of designating the beginning and end of this navigation interval exists, one has been devised for this analysis. Assuming the normal order of events whereby the aircraft turns on to and stabilizes on the localizer, descends, and finally lands; the termination of the interval, i.e., aircraft touchdown, is obvious. However, determination of the beginning of the interval is not trivial. This requires the identification of the turn-on and subsequent localizer stabilization point. Since it is difficult to objectively define the first point at which the aircraft is stable, two methods of defining it were used. These methods are referred to as the STABLE1 algorithm and the STABLE2 algorithm (see appendix D). The algorithms generate separate navigation intervals for each aircraft. Each algorithm's intervals are then grouped into "views."

The Memphis report (reference 14) used four distinct views which were referred to as the Full View, View 1, View 2, and View 3. Each successive view is a subset of its predecessor. The objective was to progress with each successive view towards a more conservative definition of navigation where View 1 is the least and View 4 is the most conservative. Navigation, once again, refers to the flightpath of the aircraft after it has acquired and become stabilized on the ILS localizer. The Memphis Full View referred to a file containing all the data for each track without imposing the requirement that the aircraft be stabilized on, or had even acquired the localizer. The Full View was considered unimportant for the purposes of this analysis and was not used. Variants of the Memphis Views 1, 2, and 3 were used in this analysis and are defined in the following subsections.

4.1.2.1 View 1.

View 1 considers the entire sample of recorded simultaneous ILS approaches. It contains:

a. A small, final amount of the turn-on segment.
b. The entire overshoot segment if overshoot exists.
c. The entire navigation segment.

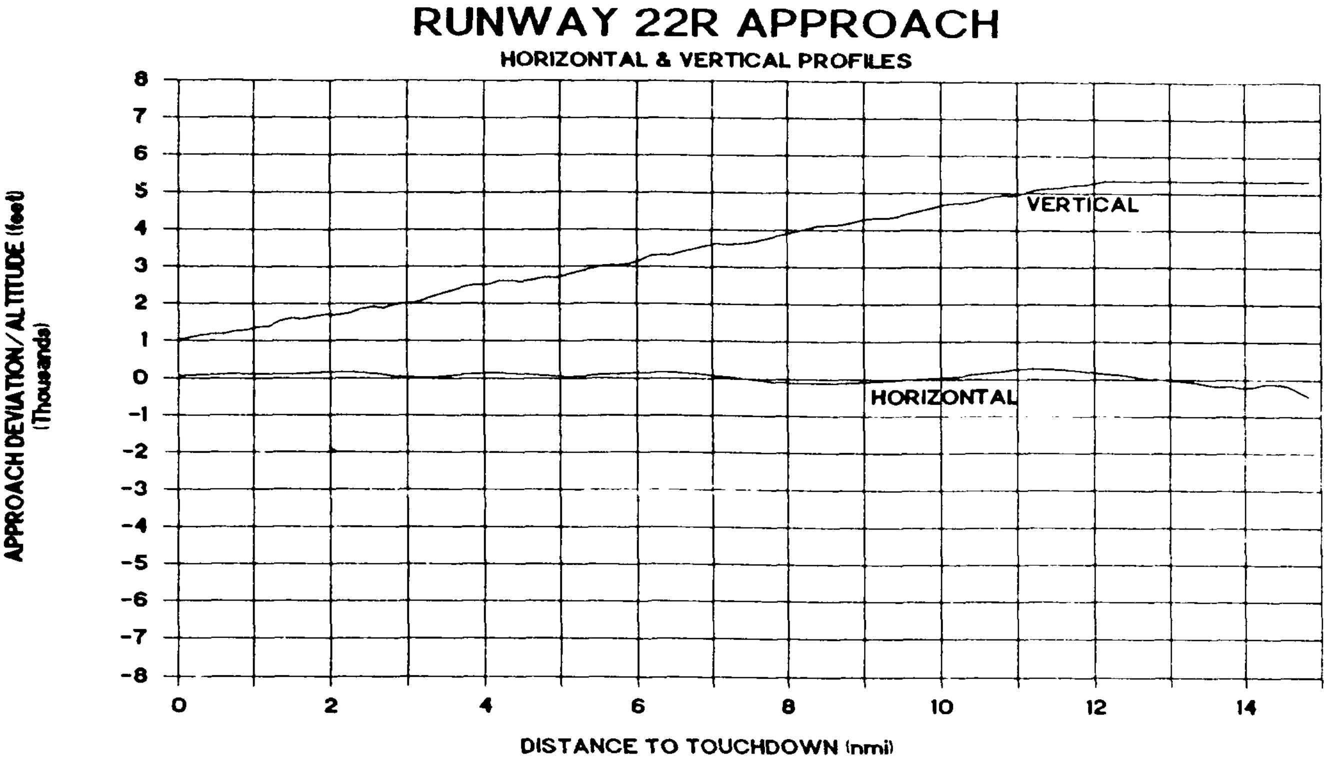


FIGURE 4.3 TYPICAL CENTERLINE APPROACH IN THE HORIZONTAL PLANE

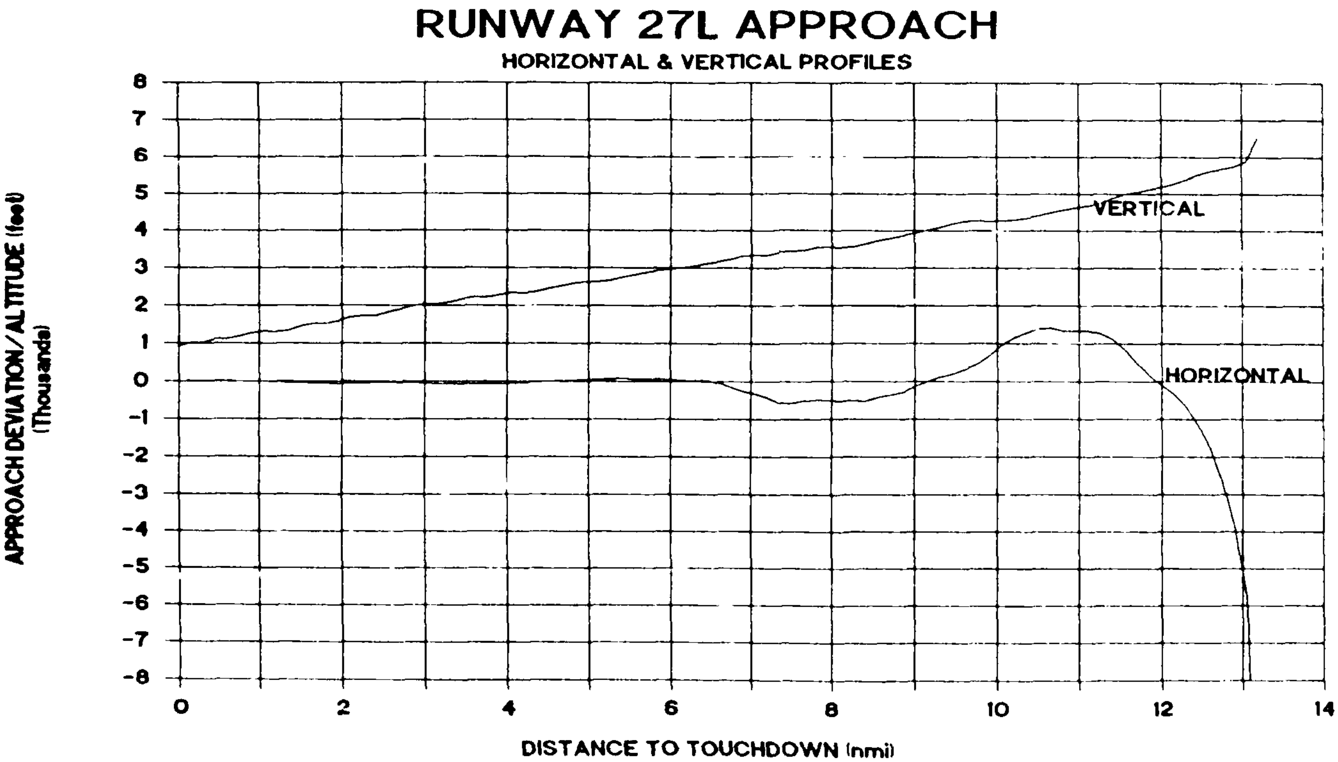


FIGURE 4.4 INITIAL OVERSHOOT APPROACH IN THE HORIZONTAL PLANE

Thus, the approach base-leg is eliminated with this view. View 1 is generated via the STABLE1 algorithm. STABLE1 deletes all track data previous to the point at which the aircraft first came within 500 feet of the extended runway centerline (see appendix D).

4.1.2.2 View 2.

View 2 considers the entire sample of recorded simultaneous ILS approaches. It contains:

a. A small amount of the final turn-on segment if there is no significant, initial overshoot, or if a significant initial overshoot exists, no turn-on, but a small amount if the initial overshoot segment.

b. The entire navigation segment.

View 2 is also an attempt to identify just the track data beginning at the point when altitude separation has first been lost between aircraft on adjacent parallel approaches and ending at aircraft touchdown. View 2 was generated via STABLE2 which uses a sophisticated algorithm whose pseudocode is detailed in appendix D. STABLE2 considers both an aircraft's altitude and its deviation from the extended runway centerline to discern the initial point of localizer stabilization or loss of altitude separation with an aircraft on the adjacent approach, whichever comes first. View 2 gives the best estimate of how the general population of simultaneous ILS approaches at ORD navigate the ILS.

4.1.2.3 View 3.

View 3 contains only the View 2 tracks which are deemed stabilized on the localizer by range 10.5 miles from touchdown. In addition to eliminating those aircraft which, although on the localizer, were not judged stable by 10.5 miles, this also eliminates all aircraft which turned-on to the localizer inside of 10.5 miles. View 3 was generated via the combination of STABLE2 and the 10.5 mile constraint. It is a subset of view 2 tracks. View 3 tests the hypothesis that those aircraft stabilized on the localizer at a distance from touchdown sufficient to allow localizer stabilization before glide slope intercept will exhibit cleaner navigation than those that have less distance to stabilize and are frequently already descending while still stabilizing.

4.2 DATA PRESENTATION AND INTERPRETATION.

4.2.1 Data Presentation.

4.2.1.1 Data Groups.

There were 3197 simultaneous ILS approach tracks suitable for analysis in the entire sample. The sample is described using the following groupings:

a. Runway approached

b. Airframe type

c. Air user category

d. Ceiling and visibility

e. Air carrier designation

f. Stabilization range from runway threshold

4.2.1.1.1 Runway.

The distribution of approach data follows (see also figure 4.5):

Runway	# of Tracks	% of Total
04L	0	0.0
04R	0	0.0
09L	378	11.8
09R	394	12.3
14L	328	10.2
14R	330	10.3
22L	40	1.3
22R	75	2.3
27L	726	22.7
27R	660	20.6
32L	145	4.5
32R	122	3.8
	3197	100.0

The runway 27L/R pair account for over 43 percent of the entire sample. This is fortuitous in that excellent radar coverage was provided through touchdown for these runways.

4.2.1.1.2 Airframe.

Percentages of the seven most numerous airframes collected are shown in figure 4.6. The airframes for which 10 or more were observed in the sample are listed below:

AC Type	Full Name	Engine Type	# of Engines	Gross Weight	# in Sample
B727	Boeing 727	J	3	170000	1080
B737	Boeing 737	J	2	111000	556
MD80	McDonnell Douglas DC-9 Model 80	J	2	140000	353
DC10H	McDonnell Douglas DC-10	J	3	455000	236
SHD6	Short Brothers 360	T	2	26000	199
DC9	McDonnell Douglas DC-9	J	2	98000	166
FK27	Fokker F-27 Friendship	J	2	45000	152
B767H	Boeing 767	J	2	312000	105
BA46	British Aerospace 146	J	4	74600	87
DC87H	McDonnel Douglas DC-8 Model 70	J	4	325000	72
AT42	Aerospatiale/Aeritalio ATR 42	T	2	32446	70
B747H	Boeing 747	J	4	833000	37
SW4	Swearingen Avia. MerlinIV/Metr	T	2	12500	28
	unknown aircraft types				26

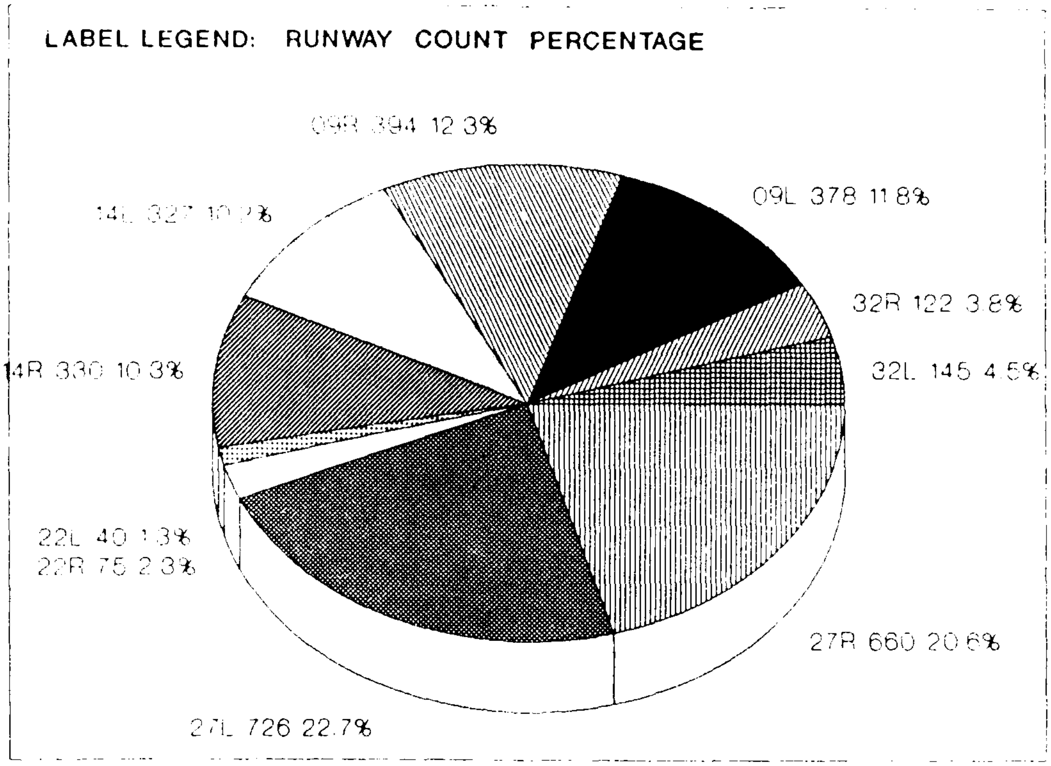


FIGURE 4.5 ORD AIRCRAFT OBSERVED PER RUNWAY

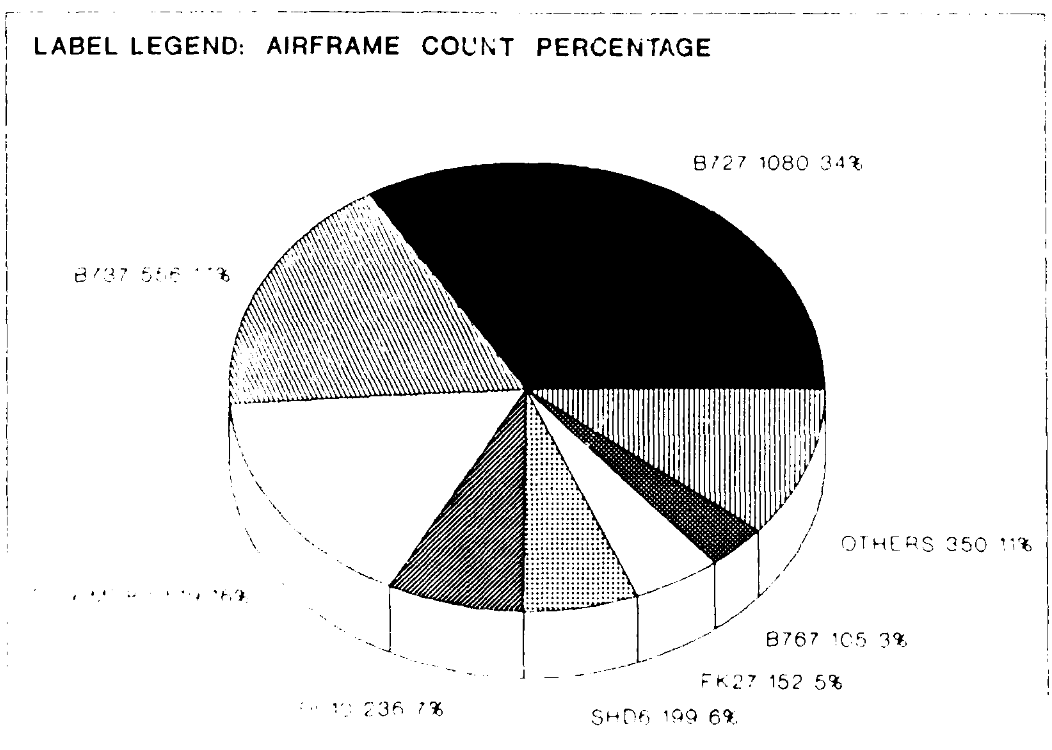


FIGURE 4.6 AIRFRAMES COLLECTED AT ORD

BE20	BeechCraft Super King Air 200	T	2	10900	19
B757	Boeing 757	J	2	220000	18
BE02	Beechcraft	T	2	10900	12
BE99	BeechCraft C-99 Airliner	T	2	10900	12
LR35	Lear LR-35	J	2	9154	10

Engine Type: J=turboJet, T=Turboprop, P=Piston
Gross Weight is in pounds.

4.2.1.1.3 User Category.

The sample was classified according to the following user categories (see also figure 4.7):

User Category	# in Sample	% of Total
Large Air Carrier	2526	79.0
Air Taxi	558	17.5
General Aviation	97	3.0
Military	16	0.5
	3197	100.0

4.2.1.1.4 Ceiling and Visibility.

Figure 4.8 shows percentages of tracks collected under the four ceiling types considered. The numbers collected under various combinations of ceilings and visibilities are shown below:

		Ceiling (ft) 500 or Less	501 to 800	801 to 1100	1101 or More	Visibility Totals	
Visibility (nmi)	< 1	193	106	0	300	599	19%
	1 to 2	262	517	11	191	981	30%
	2 to 3	284	478	228	123	1113	35%
	> 3	60	160	105	179	504	16%
Ceiling Totals		799	1261	344	793	3197	100%
		25%	39%	11%	25%		

4.2.1.1.5 Air Carrier.

The table below lists the air carriers observed in the sample.

Carrier ID	Carrier Name	# in Sample	% of Total
UAL	United Airlines	1208	39.2
AAL	American Airlines	776	25.2
SYM	Simmons Airlines	252	8.2
AWI	Air Wisconsin	237	7.7
NWA	Northwest Airlines	95	3.1
DAL	Delta Airlines	93	3.0
COA	Continental Airlines	65	2.1

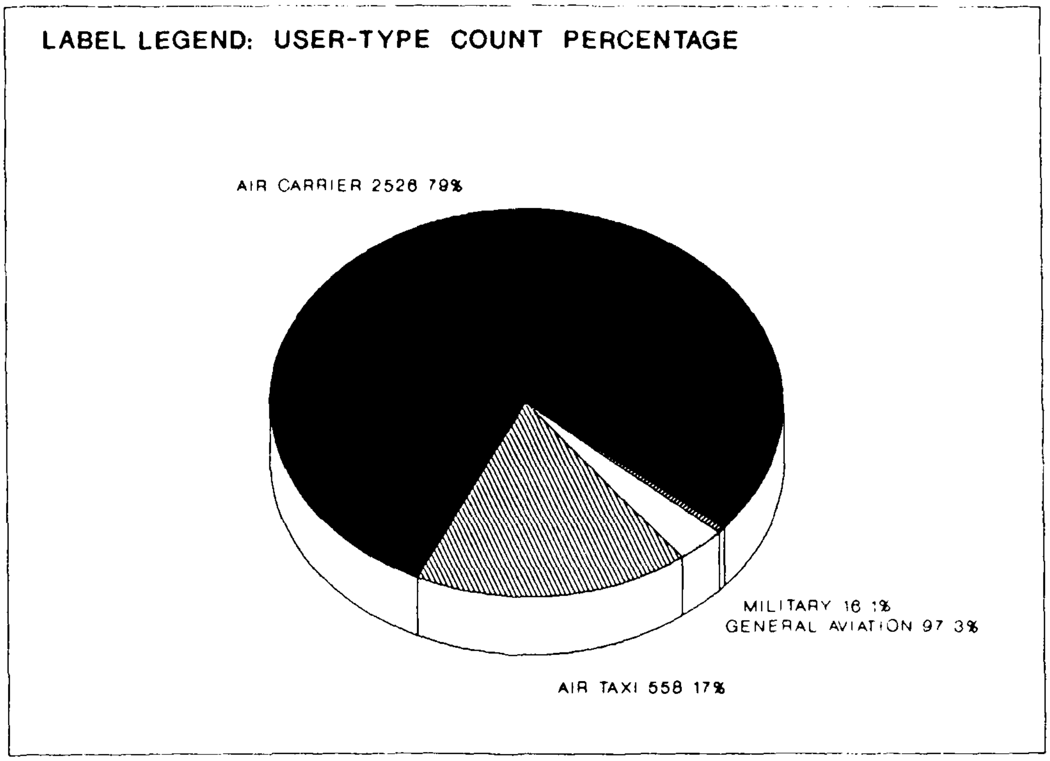


FIGURE 4.7 USER TYPES OBSERVED AT ORD

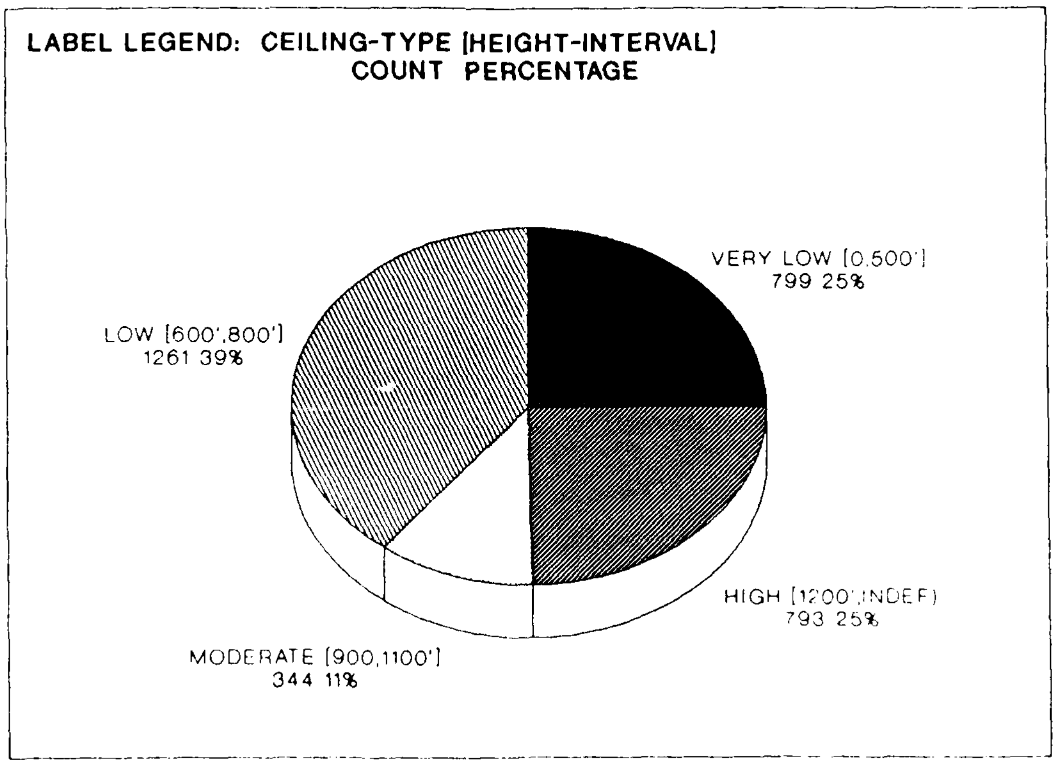


FIGURE 4.8 ORD AIRCRAFT PER CEILING TYPE

PAI	Piedmont Airlines	59	1.9
TWA	Trans World Airlines	44	1.4
USA	US Air	42	1.4
BTA	Britt Airways	33	1.1
BNF	Braniff	23	0.7
EAL	Eastern Airlines	22	0.7
GLA	Great Lakes Aviation, Ltd.	22	0.7
ACA	Air Canada	16	0.5
AWE	American West Airlines, Inc.	14	0.5
AMT	American Trans Air	11	0.4
	All Others	72	2.3
		3197	100.0

4.2.1.1.6 ILS Stability.

Figure 4.9 shows the percentage of tracks stable within the following nautical mile intervals: (0,8), [8,9), [9,10), [10,11), [11,12), [12,13), [13,14), and [15,infinity). Note that this interval terminology that is used in mathematics and uses parentheses () for noninclusiveness and brackets [] for inclusiveness. For example: [8,9) means the interval from 8 to 9 not including 9. Another way to express this is 8<=X<9 where in this case X = Distance to touchdown along the extended runway centerline.

4.3 DATA INTERPRETATION.

As stated previously, the three views were constructed using the two stabilization algorithms. The result is a comparison of a quite loose definition of aircraft navigation along the ILS (View 1) with a stricter definition (View 2) and a yet stricter definition (View 3). Summary statistics were computed using all three views to quantify the level of dispersion about the ILS centerline. These statistics are discussed in the following subsections.

4.3.1 Track ILS Navigation Statistics.

(Note: Tables referred to in the following sections can be found in appendix F.)

4.3.1.1 Discussion.

The raw data was reduced (see appendix B) to yield a data base of individual track files (t,x,y,z,) for the 3197 simultaneous approaches collected under IMC. This data base was passed through processes which produced statistics from touchdown to 13 nmi from touchdown in 0.15 nmi increments. The statistics consist of the following at each 0.15 nmi increment:

Statistic	Definition
1	Number of observations
2	Mean deviation in feet from approach centerline
3	Standard deviation in feet from approach centerline

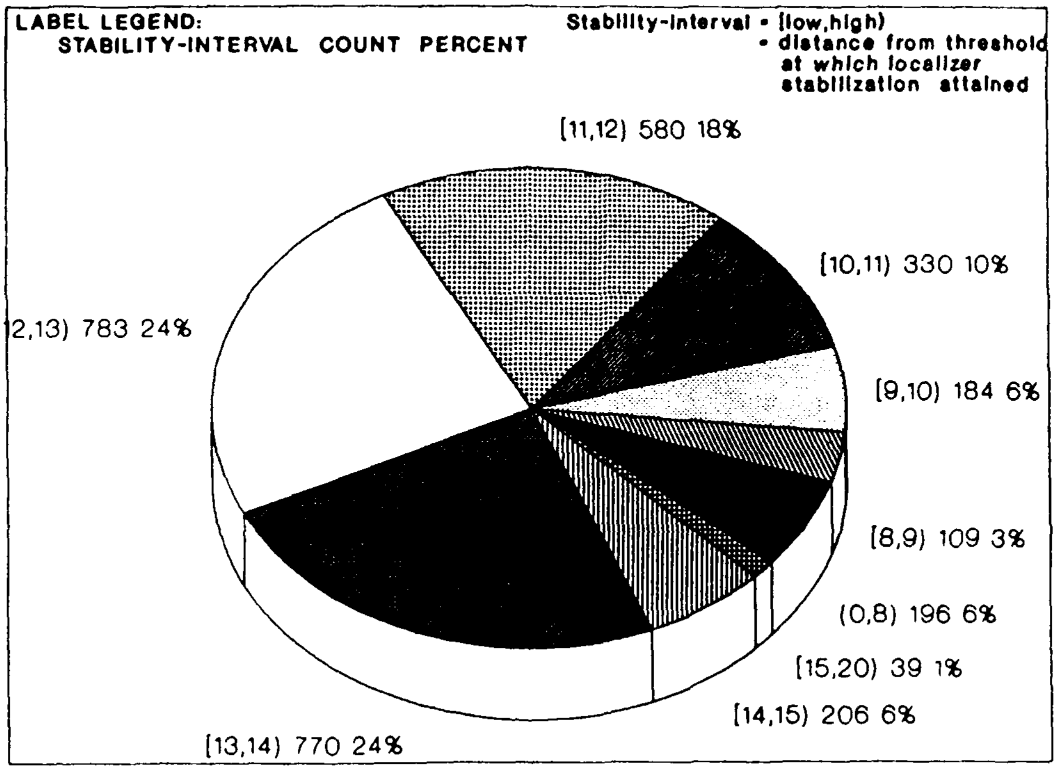


FIGURE 4.9 TRACK STABILITY INTERVALS

4 Distributions of aircraft about the extended runway centerline

5 Aircraft containment within envelopes and zones surrounding the extended runway centerline.

Statistics 1, 2, and 3 are presented collectively for the entire distribution of aircraft deviations about the extended runway centerline. Statistics 1 and 2 are also presented for each side of the centerline; i.e., away from the NTZ and toward the NTZ. Table F-1 is an example of these statistics.

Statistic 4 is the distribution of aircraft about the approach centerline. It shows numbers of aircraft within 500 feet of the centerline as well as those within 500 and 550, 550 and 600, 600 and 650, 650 and 700, 700 and 800, 800 and 900, and those greater than 900 feet for each side of the extended runway centerline. Table F-4 is an example of this statistic.

Statistic 5 shows approach track containment within hypothetical zones and envelopes. It is actually two slightly different statistics:

a. Containment within a containment envelope.

b. Containment within a containment zone.

A containment envelope (figure 4.10) can be thought of as a rectangular box surrounding the extended runway centerline. Its length extends along the approach from runway threshold to 15 miles from threshold and its width is constant and bisected by the extended runway centerline. The containment envelopes considered extend 500, 550, 600, 650, and 700 feet from extended runway centerline. They can be thought of as two NOZ's of equal width, one on each side of the extended runway centerline. Any aircraft that strays outside of the containment envelope may or may not be in the NTZ for simultaneous approaches like those collected in this study. Containment envelope statistics are, therefore, not sufficient for judging NOZ containment for simultaneous approaches. They are, however, valuable when considering containment on the inner approaches to triple or quadruple parallel runways and that is why they are being considered. Table F-7 is an example of this statistic.

A containment zone (figure 4.11) differs from a containment envelope in that it is unbounded on the side of the extended runway centerline away from the adjacent parallel approach. Thus, any aircraft that penetrates the containment zone will, by definition, be in the NTZ. The containment zone, then, is sufficient when assessing numbers of tracks entering the NTZ for simultaneous approaches. Table F-13 is an example of this statistic.

4.3.1.2 Total Sample Statistics.

Tables F-1 through F-3 list statistics 1, 2, and 3 for Views 1, 2, and 3 of the total sample. Figures 4.12 through 4.14 show these statistics in bar chart form. Figures 4.15 through 4.17 show these statistics in X/Y form. The X/Y graphs show more detail in that they contain more data points per unit distance along their abscissa than do the bar charts. The bar charts are provided for a simpler, cleaner perspective on these statistics.

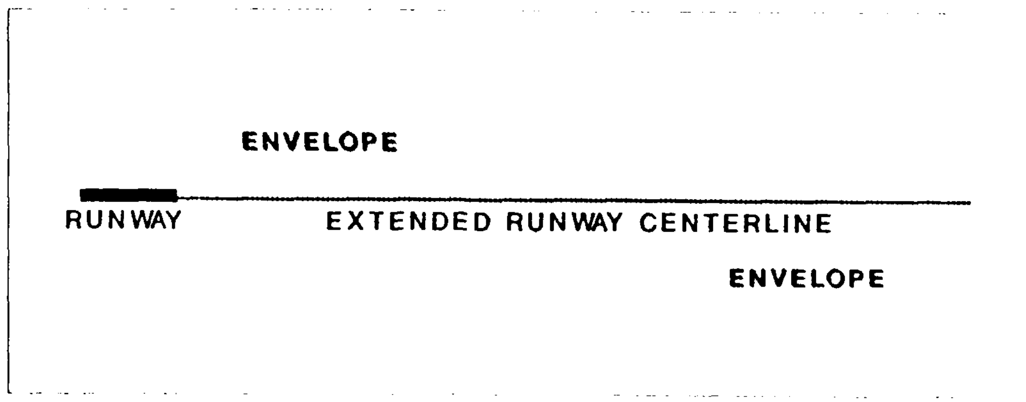


FIGURE 4.10 CONTAINMENT ENVELOPE

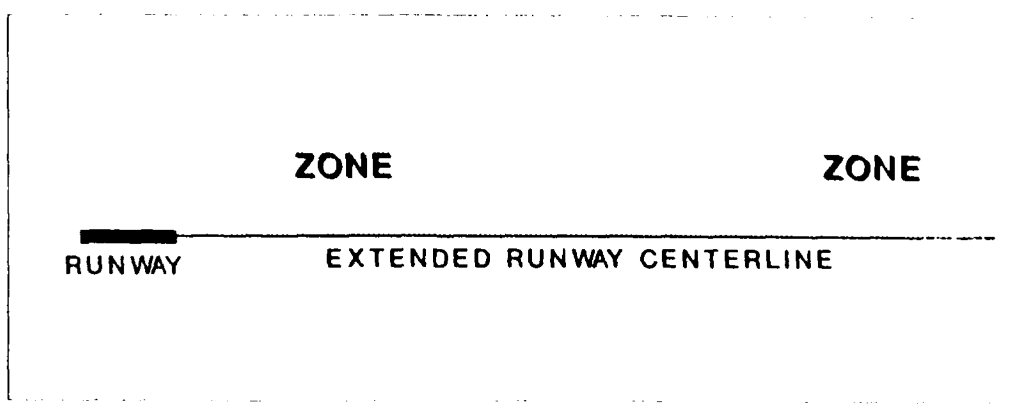


FIGURE 4.11 CONTAINMENT ZONE

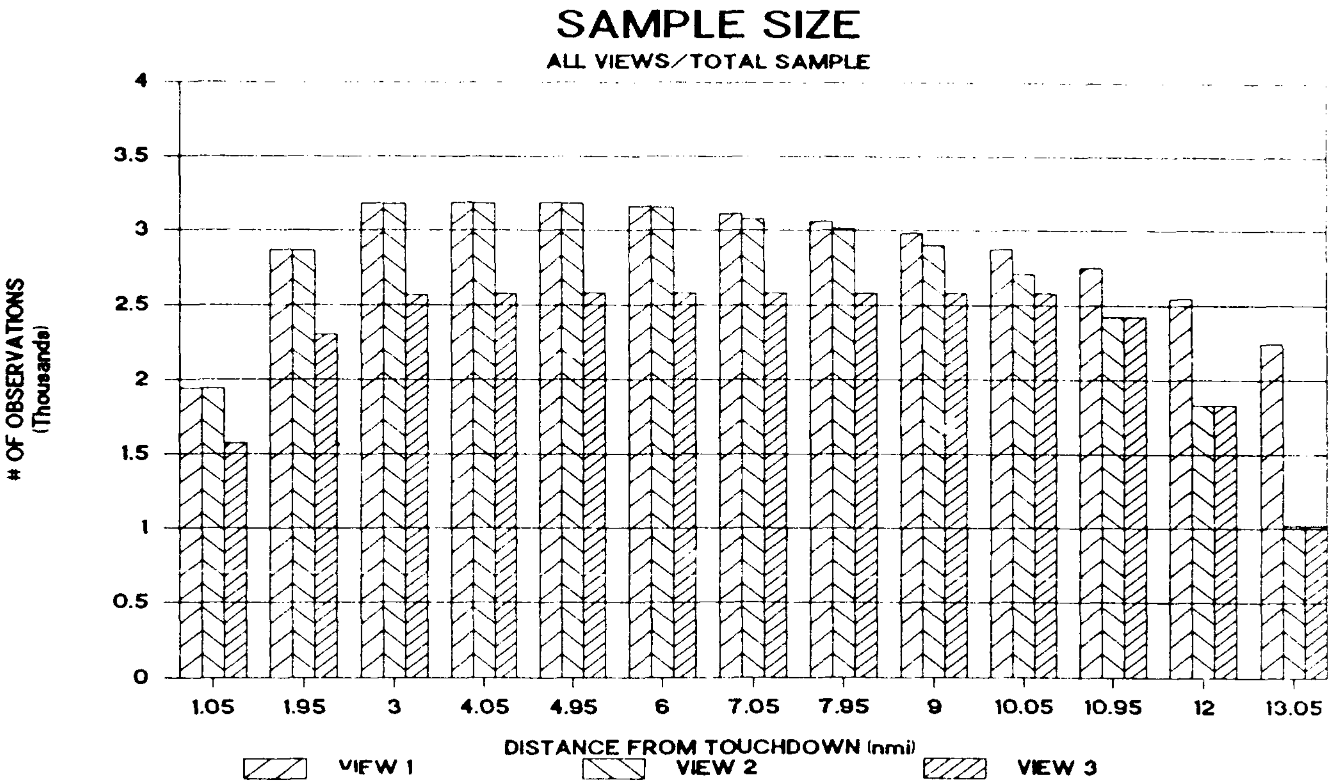


FIGURE 4.12 SAMPLE SIZE PER VIEW AT VARIOUS POINTS ALONG APPROACH (BAR)

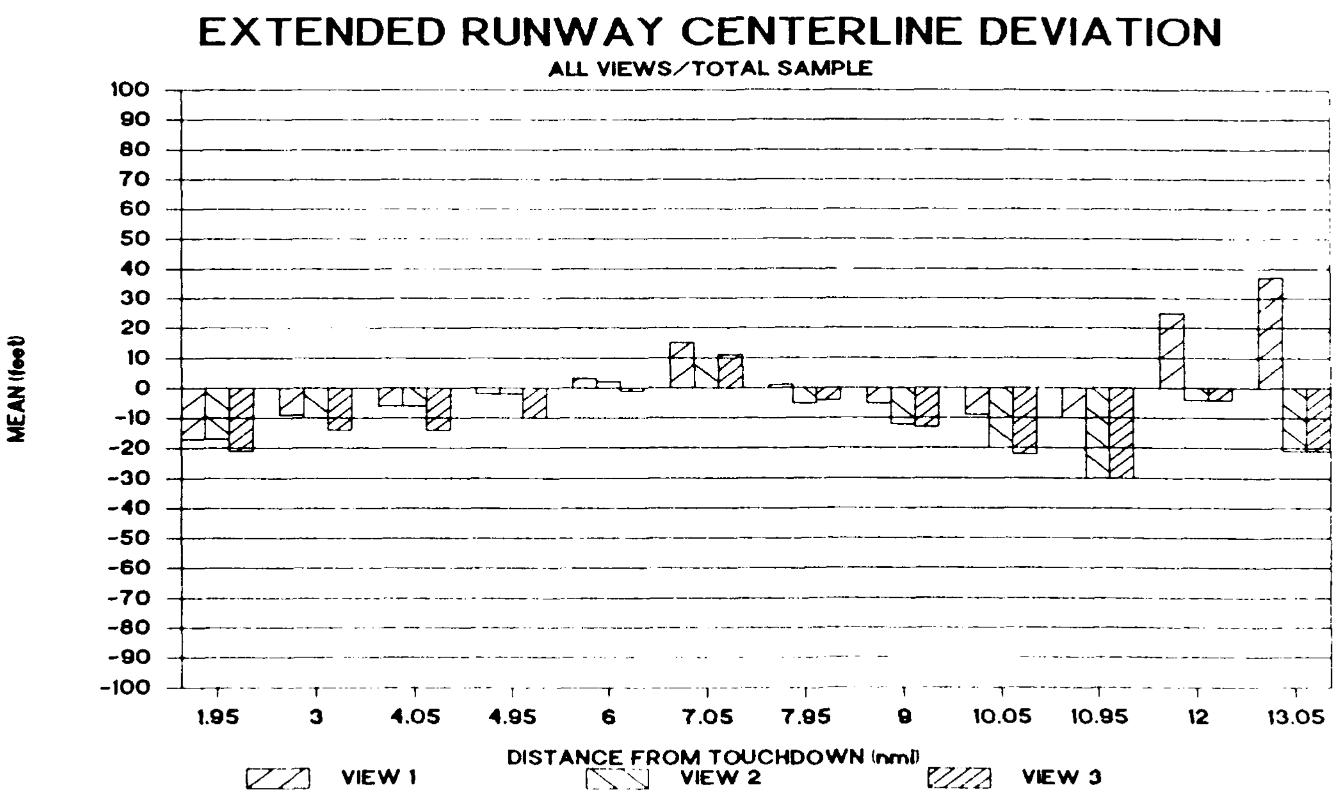


FIGURE 4.13 AVERAGE DEVIATION PER VIEW FROM APPROACH CENTERLINE (BAR)

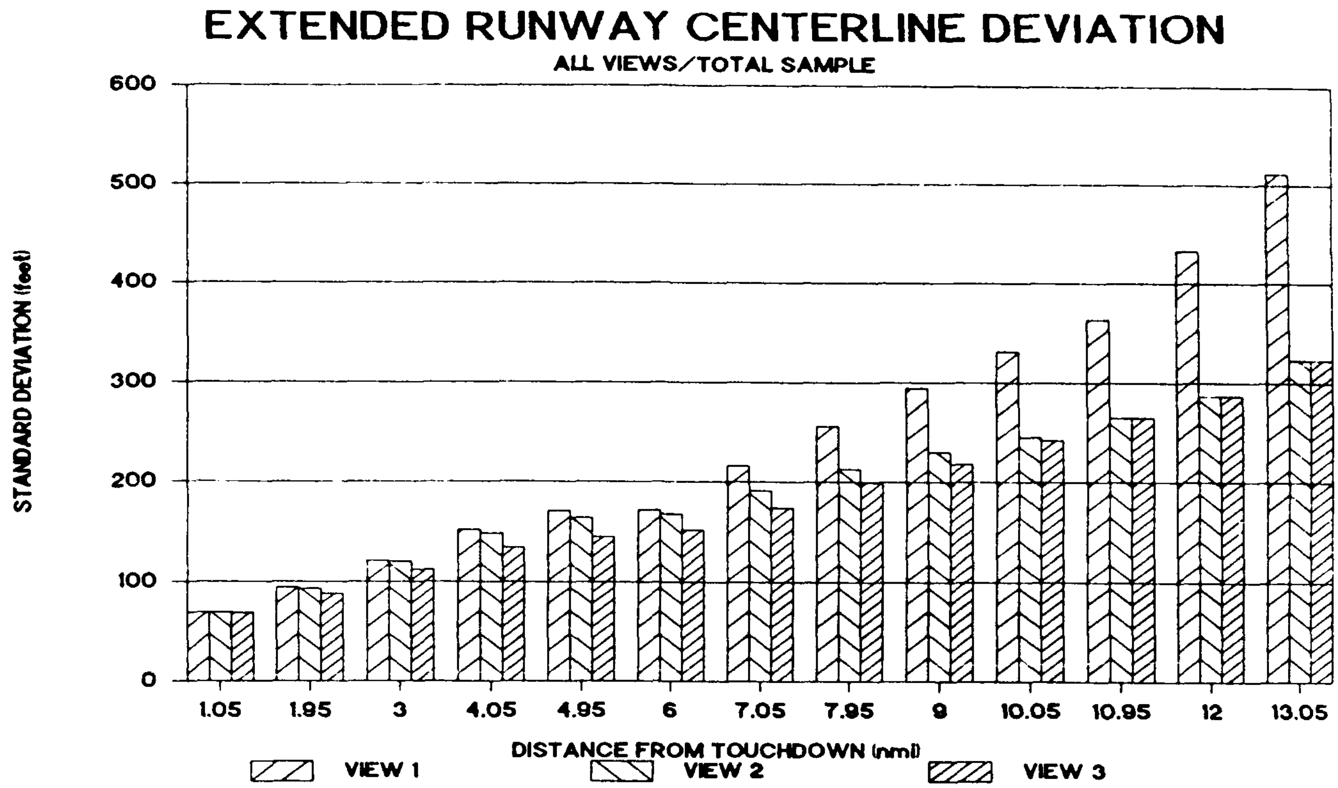


FIGURE 4.14 STANDARD DEVIATION PER VIEW FROM APPROACH CENTERLINE (BAR)

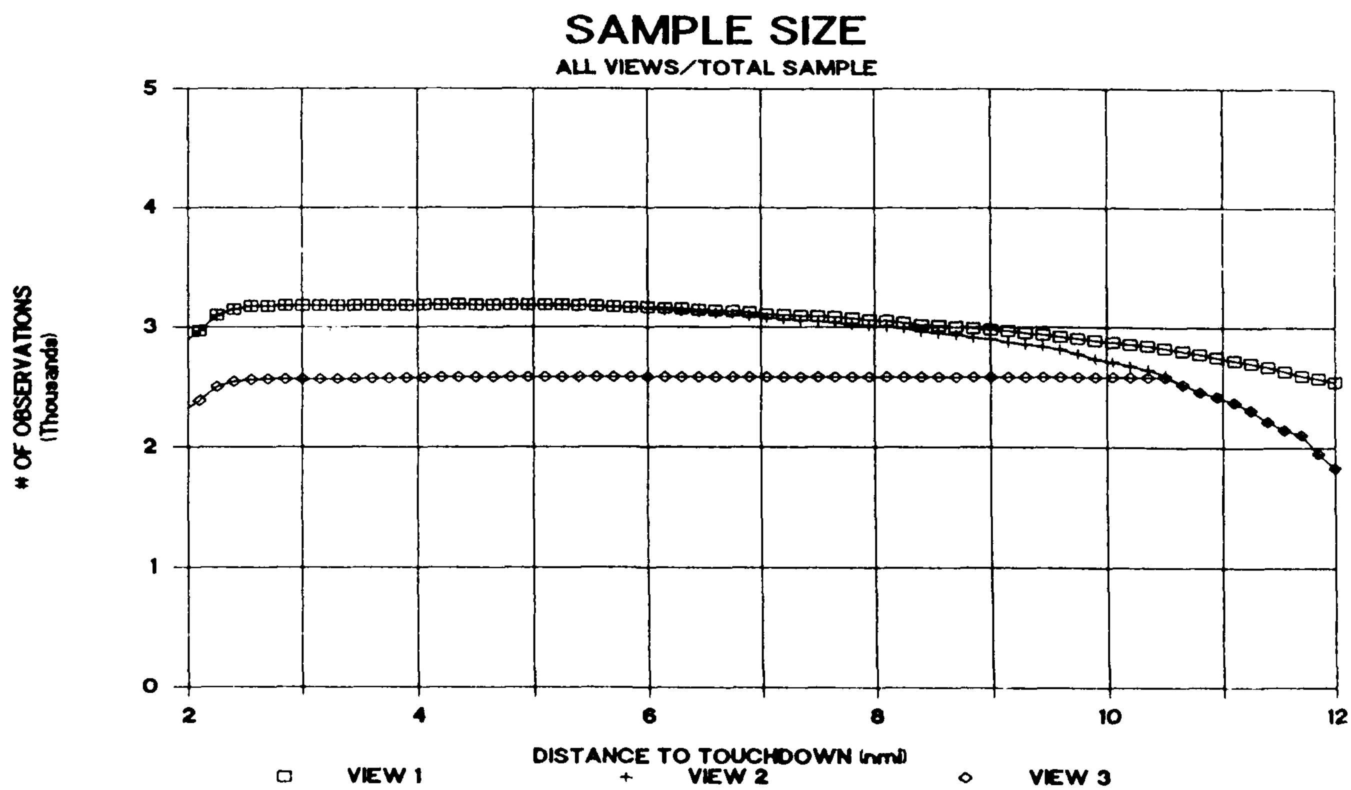


FIGURE 4.15 SAMPLE SIZE PER VIEW AT VARIOUS POINTS ALONG APPROACH (X/Y)

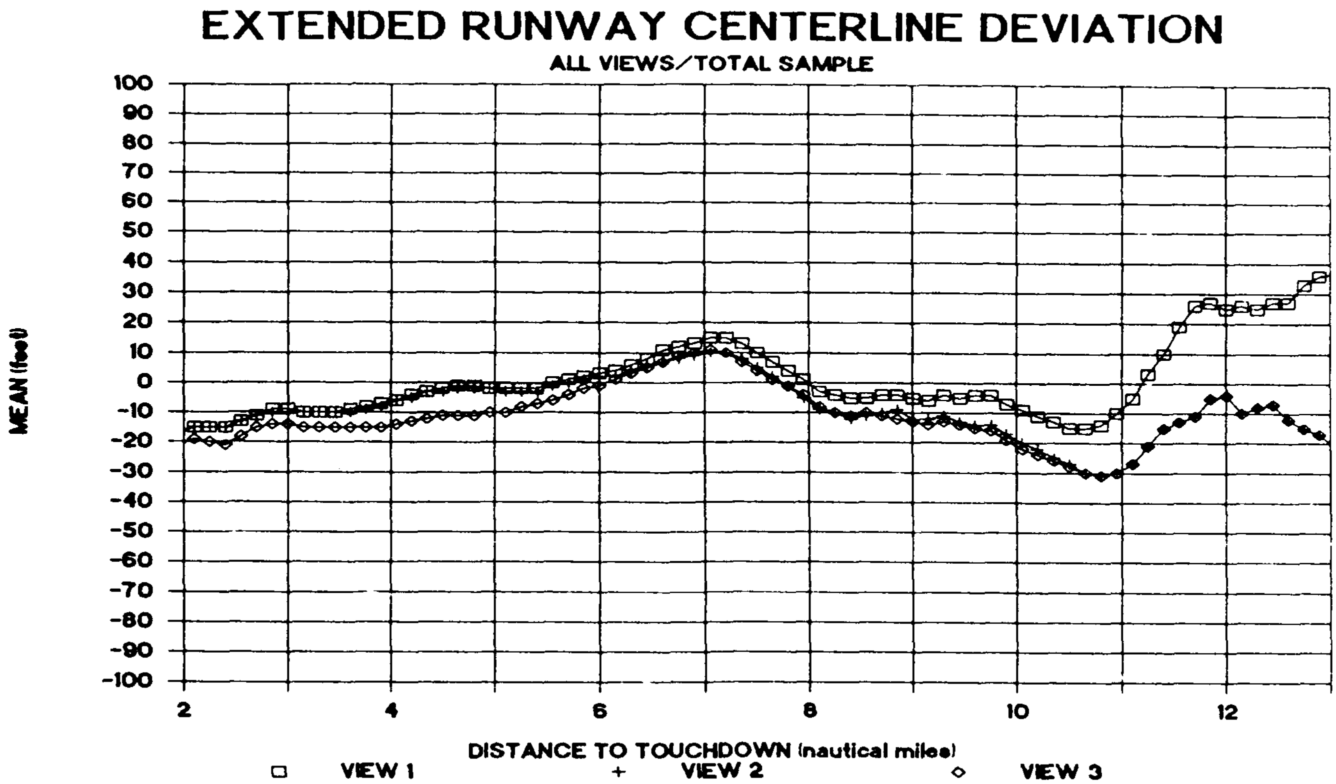


FIGURE 4.16 AVERAGE DEVIATION PER VIEW FROM APPROACH CENTERLINE (X/Y)

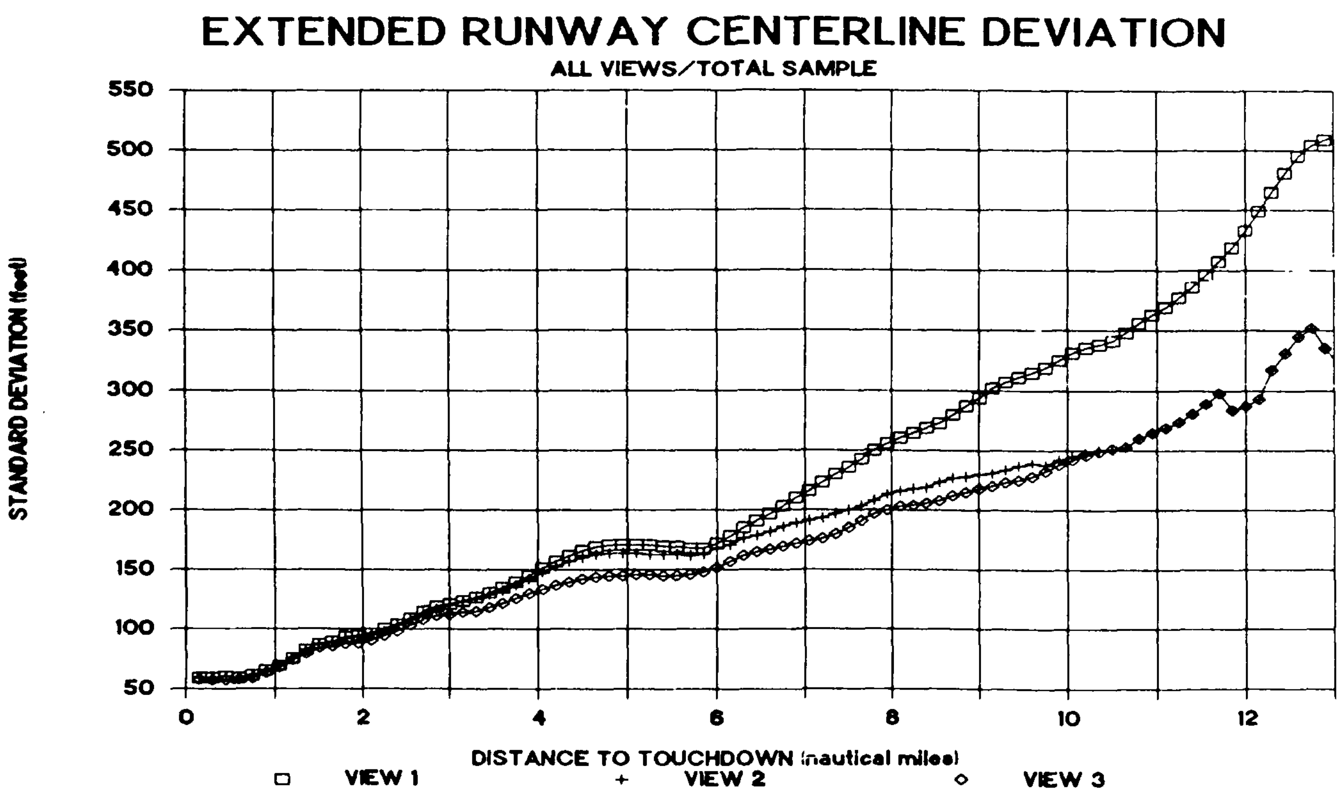


FIGURE 4.17 STANDARD DEVIATION PER VIEW FROM APPROACH CENTERLINE (X/Y)

A few things are worth noting from these figures:

a. Deviation about the extended runway centerline increases in direct proportion to distance from runway threshold.

b. If turn-on data (View 1) is considered, significantly larger centerline deviation is observed between 8 and 13 miles from touchdown when compared with stable data (Views 2 and 3)[1]. The magnitude of this difference increases in direct proportion to distance from touchdown.

c. For tracks stabilized at least 10.5 miles from threshold (View 3):

1. Slightly less deviation about the extended runway centerline is exhibited when compared with the entire sample (View 2).

2. The relationship of deviation about the extended runway centerline to distance from touchdown is nearly linear.

Figures 4.18 and 4.19 show statistics 1 and 2 for View 2. Here the tracks for the entire sample are considered. In addition, the group containing those on the side of the localizer towards the NTZ and the group containing those on the side away from the NTZ are considered separately. The following can be gleaned from these figures:

a. The average centerline deviation is directly proportional to the distance from touchdown.

b. There is no significant bias of the average track towards or away from the NTZ.

c. The average track navigates the ILS centerline from 13 nmi through touchdown with an average deviation between 0 and 30 feet.

Tables F-4 though F-6 list distributions of tracks surrounding the extended runway centerline (statistic 4) for the entire sample.

Containment within containment envelopes surrounding the extended runway centerline (statistic 5a) is shown in tables F-7 through F-12 for the entire sample. Containment within containment zones (statistic 5b) surrounding the extended runway centerline is presented in Tables F-13 through F-18 for the entire sample. Figure 4.20 provides a summary of these tables.

[1]This is consistent with the fact that 93.9% of the sample tracks are deemed stabilized by 8 miles from touchdown.

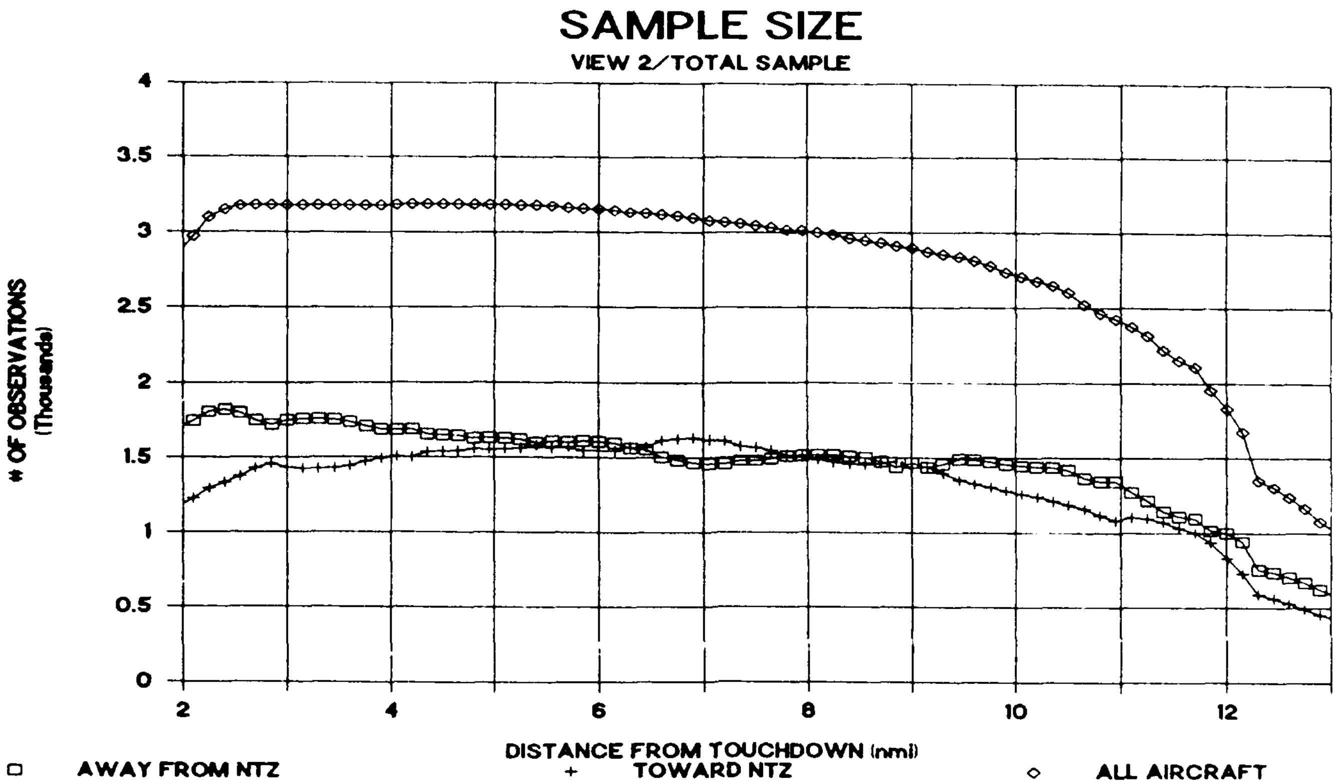


FIGURE 4.18 VIEW 2 SAMP'.E SIZE AT VARIOUS POINTS ALONG APPROACH (X/Y)

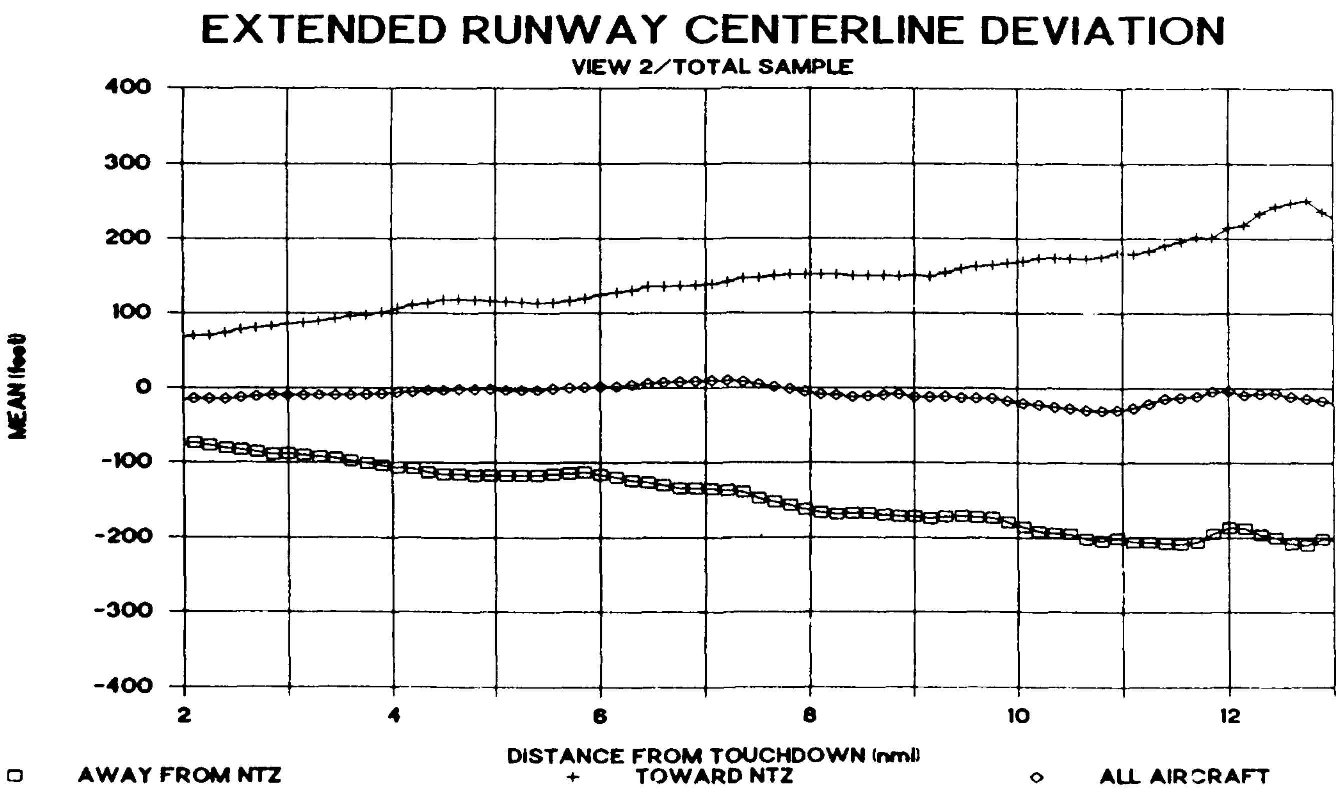


FIGURE 4.19 VIEW 2 AVERAGE DEVIATION FROM APPROACH CENTERLINE (X/Y)

Width of Containment Zone or Envelope (feet)	Percent Containment Envelope V1	V2	V3	Zone V1	V2	V3	Corresponds to* Rwy Separation (feet)
500	92%	94%	94%	96%	98%	98%	3000
550	94%	96%	96%	97%	98%	99%	3100
600	95%	97%	97%	97%	99%	99%	3200
650	96%	98%	98%	98%	99%	99%	3300
700	97%	98%	98%	98%	99%	99%	3400

Note: These percentages are valid along the approach from touchdown out to 10.5 miles from touchdown.

*These runway separations are computed by adding together the widths: left NOZ + NTZ + right NOZ, where NTZ is always 2000 feet.

FIGURE 4.20 CONTAINMENT STATISTICS

The following interpretation can be made from figure 4.20:

a. Considering a hypothetical zone containment case where dual parallel runways would be separated by as little as 3000 feet, only 4% of the observed Chicago tracks would have entered the NTZ from 10.5 miles to touchdown when considering turn on and stabilization (View 1). If turn on and stabilization is eliminated (Views 2, 3), then only 2% of the tracks leave this same NOZ and enter the NTZ.

b. Considering a hypothetical envelope containment case where triple or quadruple parallel runways would be separated by 3000 feet, then 8% of the ORD View 1 tracks and 6 percent of the View 2 tracks would enter an NTZ for an inner approach.

4.3.1.3 Group Statistics.

Data were grouped in order to allow direct comparison with data obtained in the Memphis study (reference 22).

4.3.1.3.1 Air Taxis vs Large Air Carriers.

The Memphis study found a significant difference between ILS navigation of large air carriers and air taxis. Tables F-19 and F-20 show View 2 statistics 1, 2, and 3 for air carriers and air taxis, respectively. Figures 4.21 and 4.22 provide plots for these groups compared with the general sample. Here, as in Memphis, the air taxi sample has a more biased average deviation and a significantly larger standard deviation from 13 through approximately 2.5 miles from touchdown when compared to large air carriers. Tables F-21 and F-22 show View 2 statistic 5b for air taxis only. Table F-21 shows that at 9.75 miles from touchdown, assuming a 550-foot NOZ, 5 percent of the stabilized

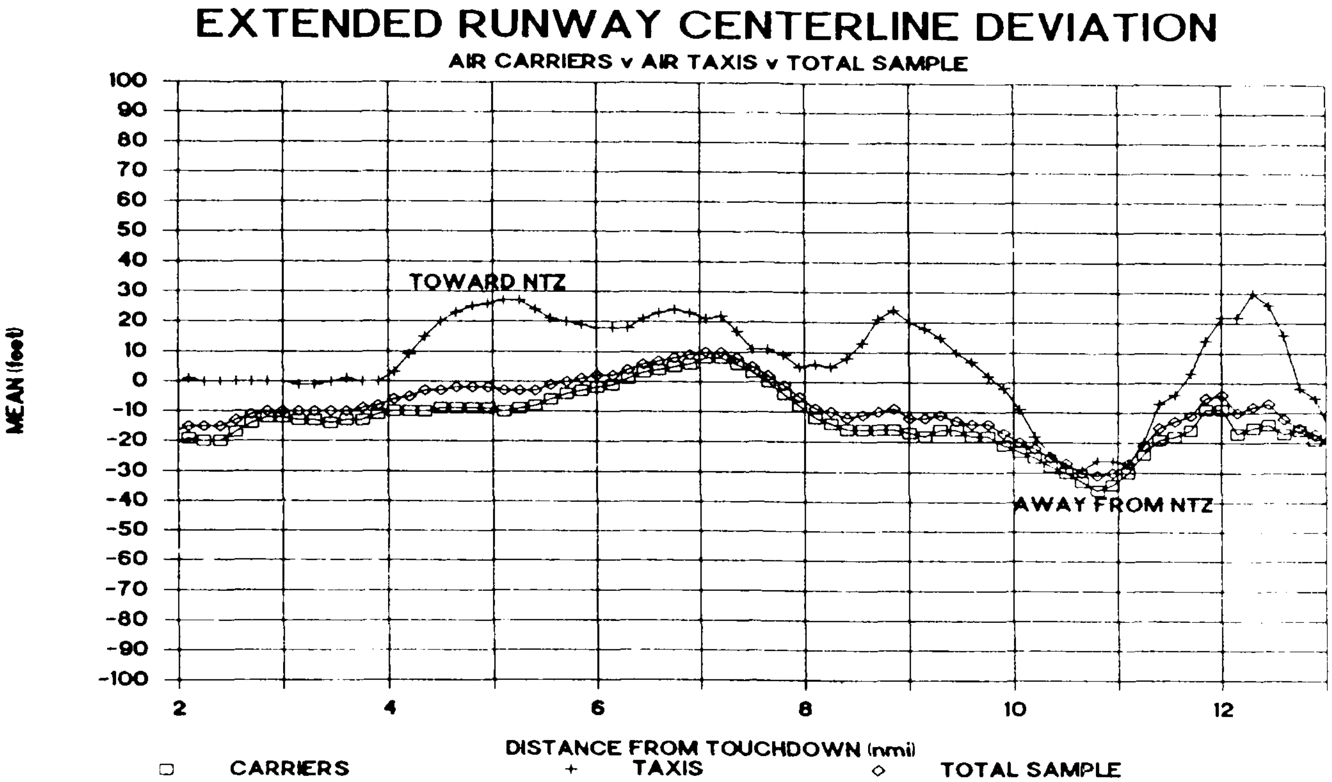


FIGURE 4.21 USER TYPE AVERAGE DEVIATION FROM APPROACH CENTERLINE (X/Y)

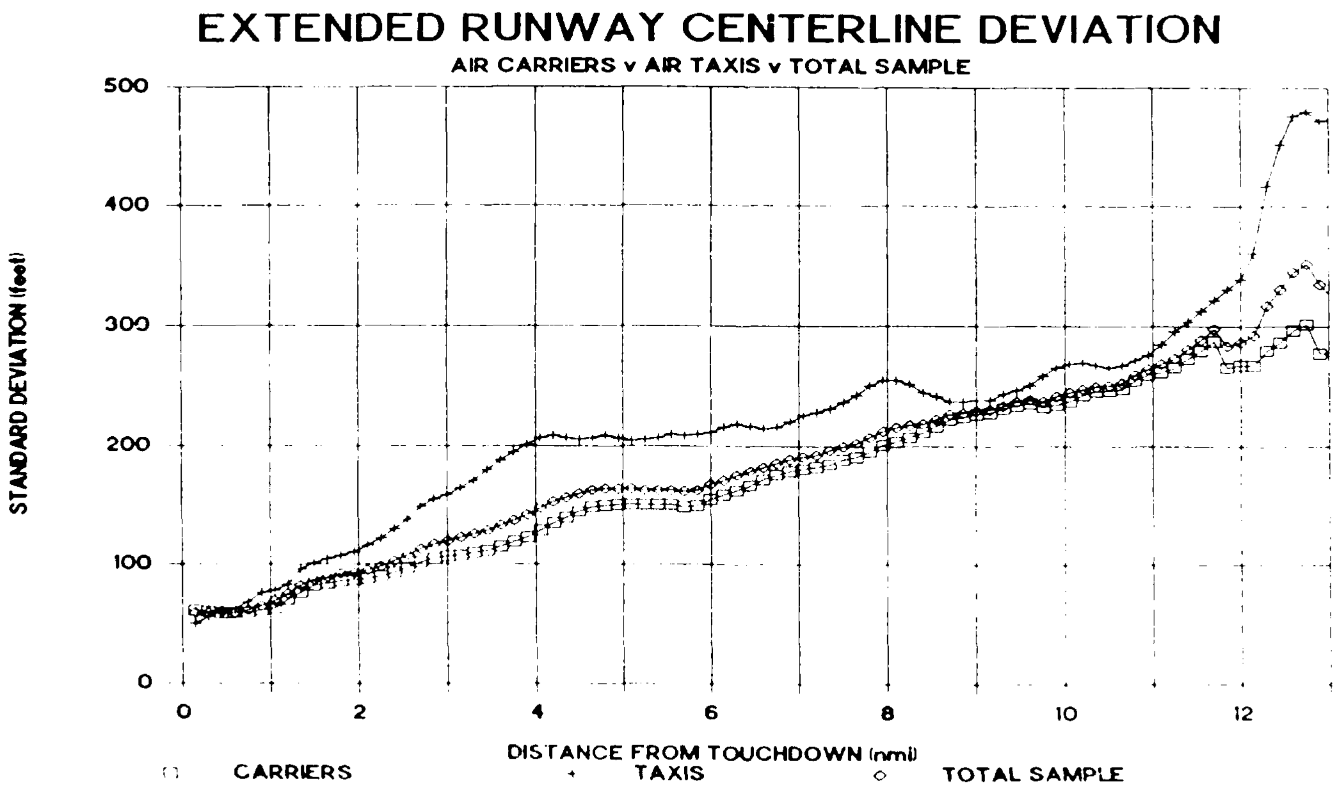


FIGURE 4.22 USER TYPE STANDARD DEVIATION FROM APPROACH CENTERLINE (X/Y)

(View 2) air taxi sample would enter the NTZ, as opposed to only 1 percent of the entire sample.

4.3.1.3.2 Runways.

Data were collected on all ORD runways except 4L and 4R. Figure 4.23 shows a comparison of the View 2 standard deviations for the six busiest runways. The approaches to these runways account for 88 percent of the data collected. The plot shows that there is, on average, a 40- to 50-foot difference between the highest and the lowest standard deviations; 14R is consistently the lowest but there is no consistent highest. These differences are not of a high enough magnitude to be considered significant.

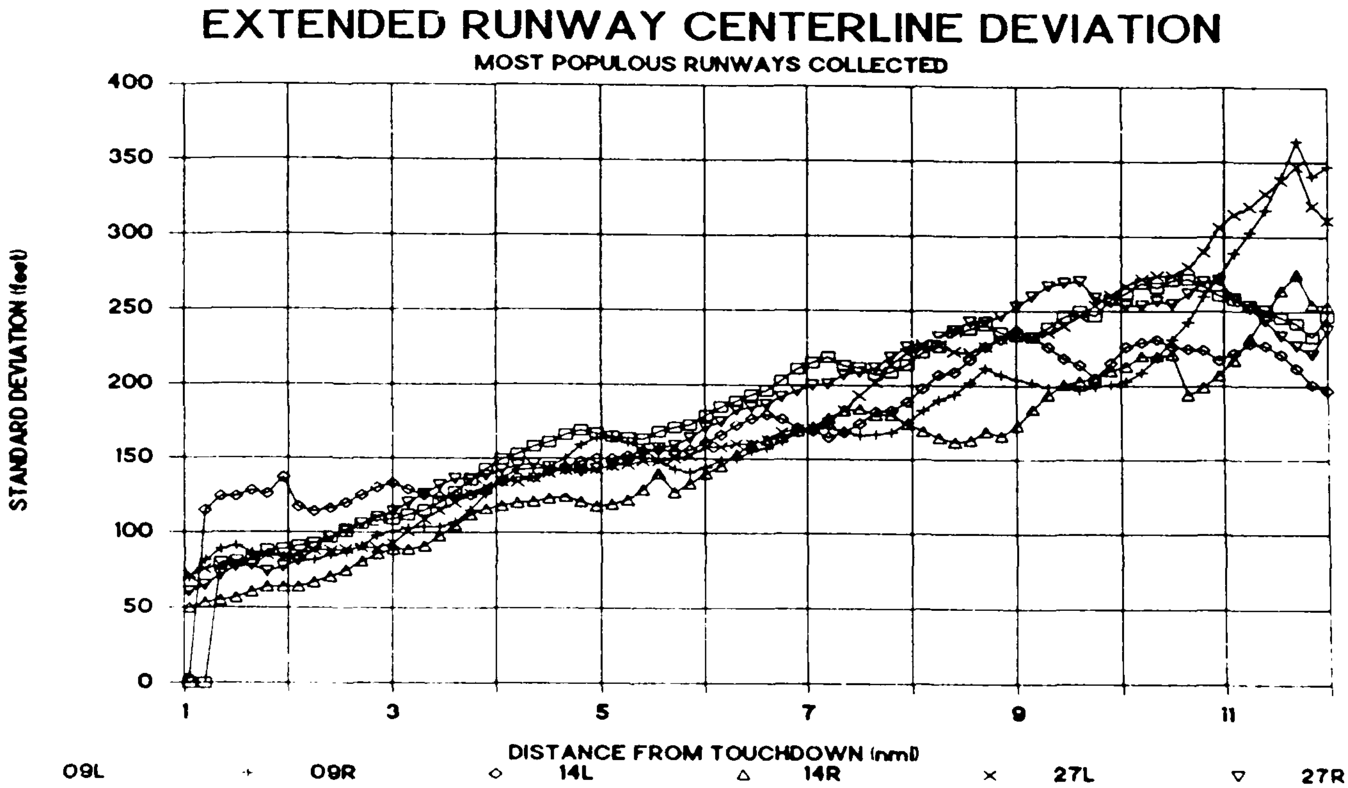


FIGURE 4.23 STANDARD DEVIATION FROM APPROACH CENTERLINE PER RUNWAY (X/Y)

5. CONCLUSIONS.

The navigational performance of 3197 aircraft flying Simultaneous instrument landing system (ILS) approaches to Chicago O'Hare International Airport has been examined. The results show that for aircraft stabilized on the localizer (View 2):

a. Dispersion about the ILS localizer is directly proportional to the distance from the runway threshold; i.e., the further from the runway, the greater the dispersion.

b. Ninety-six percent of the study aircraft remained within 550 feet of the ILS localizer from 10.5 miles from the runway threshold down to touchdown.[1]

c. Only 2 percent of the approaches would have entered the NTZ assuming a hypothetical 550 foot NOZ[2] (3100-foot runway separation).[3]

d. Aircraft that had stabilized by 10.5 miles from the runway threshold, which represents 85 percent of the entire sample, exhibited less dispersion about the ILS localizer than the overall sample.

e. Air taxis exhibited consistently more dispersion about the ILS localizer than the large air carriers; this difference ranged from a low of only a few feet at 10.5 miles to approximately 75 feet at 4 miles from the runway threshold.

f. The was no significant difference in dispersion with regard to the runway/ILS used for approaches.

It is important to note that these conclusions reference only that part of stabilized ILS navigation from touchdown out to 10.5 miles from touchdown. Conclusion "b" satisfies the request by the Industry Task Force on Airport Capacity Improvement and Delay Reduction to determine whether 95 percent of all aircraft can be expected to remain within a 550-foot NOZ from the point where 1000 feet of vertical separation is lost down to runway threshold. Conclusion "f" implies that the ILS systems for the various runways at O'Hare were performing equally well and are being properly maintained.

6. RECOMMENDATIONS.

This analysis has only considered stabilized Simultaneous Instrument Landing System (ILS) approaches from touchdown out to 10.5 nmi from touchdown. There has been some speculation that during turn-on to the approach, at distances between 14 and 20 miles out, the 1000 feet of vertical separation is not always maintained. Since there are enough approaches turned-on at these distances in the Chicago sample, further analysis could be done to consider this. A slight restructuring of the existing track data base would have to be done, however, to add in the data from 15 miles out. This is considered a minor task at this point.

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[1]This corresponds to the containment envelopes discussed in section 4.3.1.1.

[2]The minimum runway separation at Chicago O'Hare is 5400 feet (27L/27R).

[3]This corresponds to the containment zones discussed in section 4.3.1.1.

The data clearly indicates that pilots had little difficulty in executing simultaneous ILS approaches at O'Hare in almost all of the 3197 observed cases. This included 30 sessions of varying instrument meteorological conditions (IMC), some of which had extremely poor ceilings and/or visibility in rain and fog. Despite the weather conditions, an overwhelming majority of aircraft were able to navigate very close to the ILS localizer once properly stabilized. Some aircraft, however, exhibited a marked oscillation about the localizer indicating some second order control instability. The causes or underlying reasons for this behavior were not immediately evident in the preliminary analysis of the data.

Based on the data from this analysis, we are prepared to make some further recommendations:

a. The results generally support the notion that current aircraft navigation performance of a typical mix of aircraft types using an ILS could support a decreased NOZ size (closer runway separation). However, aircraft navigation performance is only one of the parameters to be considered in the overall safety and advisability of reducing runway separations. We recommend that the data from this analysis be further used in the collision risk model being developed in parallel with this effort to more accurately determine the impact of this data to the overall capacity problem.

b. There is a significant difference of navigational performance when comparing same aircraft types under similar weather conditions to the same runways. This has not been adequately explained. We recommend that further analysis of the O'Hare data be performed in an attempt to either find the underlying reasons, or to develop a methodology to do so in the future.

c. The FAA surveillance radars used to provide position reports for the study generally performed well. However, gaps did appear in the report data, as well as occasional garbled altitude and beacon codes. We recommend that further analysis be performed to establish the quality of radar performance observed. This data should be used to develop a realistic radar performance model that could be used both in fast-time simulation models and in the National Airspace System (NAS) Simulation Support Facility (NSSF) real-time simulation. This data could also be used as a benchmark to compare against ASR-9 and Mode S surveillance radars.

d. It was shown in preliminary work to this study that surveillance radar report quality was best with radar reinforced beacon reports, followed by beacon-only reports, then lastly by radar-only reports. We recommend that further analysis be performed to determine whether an enhanced tracker could be developed which would fully utilize the best characteristics of the combined primary and secondary radar target reports. This could produce significantly improved tracking, particularly with the incorporation of the new ASR-9 and Mode S radars. Tasks have been identified in the NAS Plan (September 1989) that could accomplish this: (a) Project 83: Integrated Radar Beacon Tracker in algorithmic development at Lincoln Lab, and (b) Advanced Format for Radar/Beacon Target Reports. In addition, enhanced tracking would be extremely helpful in the development of an automated parallel runway monitor aid.

e. It was also shown in preliminary work to this study that beacon target reports may contain a range bias that is attributable to variations in aircraft transponder turn around delay. This variation is, in part, related to the

strength of the received interrogation (thus range), and, in part, due to manufacturing tolerances. It must be realized, however, that transponders operating within accepted turn around tolerances (3 usec plus or minus 0.5 usecs) may effectively report a range bias of plus or minus 245 feet of actual position. We recommend that further work be done to evaluate expected transponder performance using a suitable sample size. Furthermore, the effect of range errors can be minimized for the purpose of tracking lateral deviation of aircraft flying the ILS by siting the radar between the parallel runways. With this configuration, lateral deviation about the ILS can be measured primarily with the radar reported azimuth (which is not subject to a transponder bias). Therefore, we also recommend an evaluation of radar siting and performance at airports currently expected to be impacted by a reduction in runway separation criteria.

f. The data represents a significant data base of typical ILS navigation performance. We recommend that this data be further used to develop a realistic ILS model that could be used, like the radar model, both in fast-time simulation models and in the NSSF real-time simulation.

g. The controller is currently presented with three distinct representations of each aircraft's position on the Data Entry and Display System (DEDS) consoles: (1) an analog "blip" generated directly on the DEDS using the ASR primary radar video (this blip is used to control traffic); (2) an analog "blip" generated directly on the DEDS using the Air Traffic Control Radar Beacon System (ATCRBS) secondary surveillance radar video; and (3) a digital (controller) symbol generated by the ARTS computer. A data block connected by a leader to the symbol provides additional information to the controller such as aircraft ID, velocity, altitude, and beacon code. The position of the digital symbol is the ARTS tracking algorithm's predicted target position which has been corrected using the correlated position of the target (beacon, radar, or combined beacon/radar). The corrected position is actually a smoothing of the raw target position referred to as track-oriented smoothing. A sufficient number of consecutive, missing or garbled beacon reports from the ATCRBS will cause the ARTS generated aircraft tracks to "coast." While coasting the digital symbol position is based solely on the ARTS tracker's predicted position. In this condition the digital target position is extremely suspect. In addition, the ARTS IIIA software program does not normally generate aircraft tracks or predicted position from the primary Airport Surveillance Radar (ASR) radar-only surveillance reports.

Because of these considerations, we recommend that a new generation of high resolution display technology be used to monitor closely spaced approach operations. This display should present a single, accurately placed symbol for each target. An enhanced tracker should be developed which will exploit the best performance characteristics of the primary and secondary surveillance radar systems used. An effective alert capability would also be very useful.

h. It is recommended that the project team collaborate and share findings and results of this study with other groups within the Federal Aviation Administration (FAA), as well as outside parties, concerned with the airport capacity problem. Only through mutual cooperation will this very difficult and complex problem be solved in a reasonable period of time.

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APPENDIX A

DATA COLLECTION FILES

The data files discussed here are those produced during the collection and reduction activities. They are separated into two groups, raw data files and reduced data files.

A.1 RAW DATA FILES.
What follows is a description of the contents of the raw data files which are produced at the time of field collection.

A.1.1 SRAP.

The raw SRAP data is recorded onto a disk file whose name has the following format **Smddhhmm.DAT**:

where -- S = the letter "S"
m = the MONTH (1 thru 9, A for October, B for November C for December)
dd = day of month-2 digits (01 to 31)
hh = HOUR of start of test (00 to 23)
mm = MINUTE of start of test (00 to 59)

From the raw SRAP file[1] the following data is extracted:

a. Time in hours, minutes, seconds referenced to ORD (Central time zone)
b. Radar sector number
c. SRAP channel number (0 or 1)
d. slant range in nmi from radar
e. Azimuth Change Pulse (ACP's) (0 thru 4096)
f. Azimuth in degrees
g. Quality (0 thru 7)
h. Special Position Indicator (SPI) (not used)
i. Beacon code (0000 thru 7777)
j. Beacon code validity (0 thru 3)
k. Altitude in hundreds of feet (uncorrected)
l. Altitude validity (0 thru 3)
m. Beacon hit count
n. Message type (BO for beacon only, RB for radar reinforced beacon)

A.1.2 Interfacility.

The interfacility data is recorded onto a disk file whose name has the format Imddhhmm.AOL. The lower case letters represent the same parameters as in the raw SRAP filename (see section A.1.1). The interfacility file consists of the following data:

[1]A complete description of the SRAP raw data format can be found in SENSOR RECEIVER AND PROCESSOR to IBM PERSONAL COMPUTER DESIGN and LOGIC (Preliminary) by J. Thomas, May 23, 1988.

a. ARR (arrival)
b. Time in hours and minutes with respect to ORD
c. Beacon code (0000 thru 7777)
d. ACID (e.g., UAL923)
e. ACTYPE (e.g., B737)
f. Approach fix (e.g., JOT)
g. Altitude at fix in hundreds of feet (e.g., 100 for 10,000 feet)

A.1.3 Low Level Windshear Alert System (LLWAS).

The LLWAS data are recorded onto a disk file whose name has the format Smddhhmm.LWS. The lower case letters represent the same parameters as in the raw SRAP filename (see section A.1.1). The LLWAS file consists of a packed version of the LLWAS maintenance video display which is updated every 10 seconds. This display contains a full screen of information, only a fraction of which is of interest to this study. Therefore, the only data listed here is that to be used through the following reduction and analysis. The reader is directed to the Enhanced Low Level Windshear Alert System Instruction Manual for further information on what is contained on the maintenance display.

a. LLWAS speed in knots
b. LLWAS wind direction in degrees with respect to true north
c. LLWAS gust in knots
d. LLWAS Center Field Average wind speed
e. LLWAS Center Field Average wind direction

A.1.4 Runway Sensors.

The runway sensor data, or RCMS data as it is sometimes referred to (in reference to the Runway Configuration Management System project that is responsible for making it accessible to this effort), is recorded onto a disk file whose name has the format Smddhhmm.RCM. The lower case letters represent the same parameters as in the raw SRAP filename (see section A.1.1). The runway sensor file consists of the following data:

a. RBC 1 (Rotating Beam Ceilometer 1)
b. RBC 2 (Rotating Beam Ceilometer 2)
c. Digital Altimeter Setting Indicator 0 (DASI 0) (not used)
d. Digital Altimeter Setting Indicator 1 (DASI 1) (O'Hare DASI)
e. Digital Altimeter Setting Indicator 2 (DASI 2) (Warm standby unit)
f. 14R Runway Visual Range (RVR)
g. 14R M RVR
h. 32L RVR
i. 14L RVR
j. 14L M RVR
k. 32R RVR
l. 09L RVR
m. 27R RVR
n. 09R RVR
o. 27L RVR
p. Time in hours, minutes, and seconds

A.1.5 Weather.

The weather data are recorded onto a disk file whose name has the format **WXmmddyy.AOL**:

where -- **WX** = the letters "WX"
mm = the MONTH-2 digits (01 thru 12)
dd = day of month-2 digits (01 to 31)
yy = year-2 digits (00 to 99)
. = "."
AOL = the letters "AOL"

A typical weather file consists of the following data:

a. Date in month/day/year
b. Time in hours and minutes
c. Location (ORD)
d. Report type (SA, SP, or RA)
e. Lowest ceiling type (E, M, or W)[2]
f. Lowest ceiling height in hundreds of feet
g. Lowest sky descriptor (OVC, CLR, or BKN or ...)
h. Next lowest ceiling type (E, M, or W)
i. Next lowest ceiling height in hundreds of feet
j. Next lowest sky descriptor (OVC, CLR, or BKN or ...)
k. Visibility in nautical miles
l. Weather (rain, fog, or snow or ...)[3]
m. Sea level pressure in millibars
n. Temperature in degrees fahrenheit
o. Dewpoint in degrees fahrenheit
p. Wind direction in tens of degrees referenced to true north
q. Wind speed in knots[4]
r. Wind gust in knots
s. Altimeter setting in inches of mercury
t. Remarks[5]

(Note: for more information on this data refer to the Aviation Weather Services Manual, AC 00-45B, published jointly by FAA and NOAH.)

A.1.6 Pilot Survey.

The pilot survey data are not automatically recorded onto a disk file. Instead it must be transcribed from paper to a data base file. The data consists of the following:

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[2]The number of ceilings is variable depending on cloud layers at time of measurement.

[3]If no obstructions to visibility, weather will not be shown.

[4]If no wind gusting at measurement times, wind gust will not be shown.

[5]Remarks describe special conditions concerning any of the other data fields.

a. Date in month/day/year

b. Time in hours and minutes referenced to ORD

c. Beacon code (0000 thru 7777)

d. ACID (e.g., UAL9276)

e. Approach type (coupled, flight director, raw data)

f. Visibility conditions (IMC or VMC)

g. Altitude in hundreds of feet at which approach lights were sighted

h. Altitude in hundreds of feet at which autopilot (if used) was disengaged

(Note: the pilot data was only supplied by United Airlines for the 1989 data collection.)

A.2 REDUCED DATA FILES.

The track files created by the reduction processes consist of position reports for a single aircraft's approach. The discription of the information contained in each track file type is listed below.

FILENAME	==>	MEANING
_acid.rwy	==>	raw track file (SRAP 0) (output of TRACKS)
!acid.rwy	==>	raw track file (SRAP 1)
DATA:		HR,MN,SEC,CH,RANGE,AZMTH,BC,ALT,TYPE
@acid.rwy	==>	corrected raw track file (SRAP 0) (output of GAP)
#acid.rwy	==>	corrected raw track file (SRAP 1)
DATA:		HR,MN,SEC,CH,RANGE,AZMTH BC,ALT,TYPE
$acid.rwy	==>	GAP documentation file (SRAP 0)
^acid.rwy	==>	GAP documentation file (SRAP 1)
DATA:		list of missing scans and altitudes, multiple scans, double scans
&acid.rwy	==>	translated to cartesian coordinates, runway, origin, corrected, raw track file (SRAP 0) (output of PTTRANS)
~acid.rwy	==>	translated to cartesian coordinates, runway, origin, corrected, raw track file (SRAP 1)
DATA:		HR,MN,SEC,X,Y,Z,NTA WIDTH

'acid.rwy ==> smoothed, filtered, translated, corrected, track file (SRAP 0) (output of SM)

(acid.rwy ==> smoothed, filtered, translated, corrected, track file (SRAP 1)

DATA: HR,MN,SEC,X,Y,Z,NTZ WIDTH

(acid.rwy ==> interpolated, smoothed, filtered, translated, corrected track file (SRAP 0) (output of INTERP)

lacid.rwy ==> interpolated, smoothed, filtered, corrected track file (SRAP 1)

DATA: HR,MN,SEC,X,Y,Z,NTZ WIDTH

where: acid ==> aircraft ID (AAL1115, UAL100, ...)

rwy ==> runway designator (27L, 27R, ...)

APPENDIX B

DATA REDUCTION

The data collected at the site was brought back to the Technical Center where it was reduced to a form which could be used in the final analysis.

B.1 DATA REDUCTION PROCESSES.

Unpacking is the process whereby data, that has been recorded in a foreign format for purposes of space and efficiency, is converted to engineering units and output in a format compatible with the analysis environment. Each of the raw data files identified in appendix A must be unpacked via some process. These processes are identified here.

B.1.1 SRAP and Interfacility Data.

The radar data collected via the SRAP requires considerably more processing than any other type of data collected to prepare it for analysis. Specifically the radar data are:

a. Connverted to engineering units and sorted according to beacon code.

b. Deleted from further processing if any of the following are detected:

1. Large gap(s) in track.
2. Track is of short duration.
3. No Mode C altitude and altitude can't be had from other sources.

c. Converted to (time,x,y,z) and translated and rotated to the runway threshold being approached.

d. Filtered and smoothed to eliminate radar outliers and to obtain a more accurate estimate of aircraft position.

e. Interpolated to attain estimates of cross-track deviation at specific points along the ILS approach.

The following software programs perform these processes on the raw SRAP data with the listed results.

B.1.1.1 **SRAPUNPK.PAS.**

--> Language: Turbo PASCAL 5.0

--> Input: **Smddhhmm.DAT** (raw SRAP data test file).

--> Process: Unpacks beacon and radar reinforced beacon messages only.

--> Output: **Smddhhmm.DBF** (foxbase format).

B.1.1.2 **TRACK.FOX.**

--> **Language:** Foxbase + 2.10 programming language

--> **Input:**

a. **Smddhhmm.DAT**

b. **Imddhhmm.AOL**

--> **Process:**

a. Invokes SRAPUNPK.PAS to unpack raw SRAP data and produce SRAP foxbase file Smddhhmm.DBF.

b. Indexes Smddhhmm.DBF by session and beacon code.

c. Identifies approaching tracks with sufficient number of scans.

d. Determines runway being approached.

e. Cross references data with interfacility file Imddhhmm.AOL to obtain ACID and ACtype.

f. Appends record to master data base (MASTER.DBF) for each identified track (see Appendix C).

--> **Output:** Creates directory "Smddhhmm" and places ASCII aircraft track files **_acid.RWY** for SRAP0 and **!acid.RWY** for SRAP1 into this directory (see Appendix A).

B.1.1.3 **GAP.C.**

--> **Language:** Turbo C 2.0

--> **Inputs:**

a. All **_acid.rwy** and **!acid.rwy** files for a session directory.

b. MASTER.DBF master data base.

--> **Process:**

a. Deletes unreasonable and multiple scans.

b. Adds missed altitudes.

c. Corrects altitudes based on airport altimeter.

d. Identifies large time gaps and determines if pre and post gap data is from the same track.

e. Produces documentation explaining results.

--> **Outputs:** **@acid.rwy** (SRAP0) and **#acid.rwy** (SRAP1) corrected data files (see appendix A).
$acid.rwy (SRAP0) and **^acid.rwy** (SRAP1) documentation files (see appendix A).

AD-A232 669 CHICAGO O'HARE SIMULATANEOUS ILS APPROACH DATA COLLECTION AND ANALYSIS(U) FEDERAL AVIATION ADMINISTRATION TECH- NICAL CENTER ATLANTIC C.. 2/2

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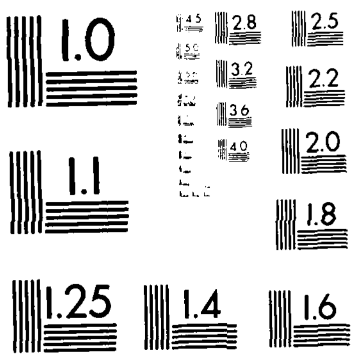

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

B.1.1.4 **PTTRANS.C.**

--> Language: Turbo C 2.0

--> Inputs: All **@acid.rwy** and **#acid.rwy** files.

--> Process: a. Converts data from (rng,az,alt) to (X,Y,Z).

b. Translates data to runway threshold identified in filename extension.

--> Outputs: **&acid.rwy** (SRAP0) and **~acid.rwy** (SRAP1) (see appendix A)

B.1.1.5 **SM.C.**

--> Language: Turbo C 2.0.

--> Inputs: All **&acid.rwy** and **~acid.rwy** files

--> Process: Filters and smooths using Lincoln Laboratory radar filtering and smoothing algorithm.

--> Outputs: **'acid.rwy** (SRAP0) and **)acid.rwy** (SRAP1) (appendix A).

B.1.1.6 **SPLINE.C.**

--> Language: Turbo C 2.0.

--> Inputs: All **'acid.rwy** and **)acid.rwy** files.

--> Process: Inserts an interpolated (T,X,Y,Z) data point at each .15 mile X increment.

--> Outputs: **(acid.rwy** (SRAP0) and **lacid.rwy** (SRAP1) (see appendix A).

B.1.2 LLWAS Data.

The raw Low Level Windshear Alert System (LLWAS) data are processed via the following programs with the listed results.

B.1.2.1 **LWASUNPK.PAS.**

--> Language: Turbo Pascal 5.0.

--> Input: Smddhhmm.LWS (raw LLWAS data file).

--> Process: Unpacks LLWAS data.

--> Output: Lmddhhmm.DBF (unpacked LLWAS data in foxbase format).

Certain LLWAS data base fields are next merged with the Master data base (see appendix C).

B.1.3 RCMS Data.

The raw Runway Configuration Management System (RCMS) data are processed via the following programs with the listed results.

B.1.3.1 RCMSUPK.PAS.

--> Language: Turbo Pascal 5.0.

--> Input: Smddhhmm.RCM (raw RCMS data file).

--> Process: Unpacks runway sensor data.

--> Output: Rmddhhmm.DBF (unpacked RCMS data in foxbase format).

Certain RCMS data base fields are next merged with the Master data base (see appendix C).

B.1.4 Weather Data.

The weather data are processed via the following programs with the listed results.

B.1.4.1 WEATHER.BAS.

--> Language: Turbo BASIC 1.0.

--> Input: WXmmddyy.AOL (raw weather data file).

--> Process: Unpacks weather data.

--> Output: WXmmddyy.DBF (unpacked weather data in foxbase format).

Certain weather data base fields are next merged with the Master data base (see appendix C).

APPENDIX C

MASTER DATA BASE

Subsequent to data collection, but prior to data analysis, all data are unpacked and merged into a data base which identifies each parallel approach collected. This data base is referred to as the Master data base. Many types of data are used to construct the Master data base which consists of information about each track and the weather which existed during the track's collection. It does not contain the tracks' radar position data. The radar position for each track is, instead, stored in the individual track files (refer to appendix A).

The Master data base contains one record for each simultaneous ILS approach. The record contains many fields each holding a track characteristic. What follows is a list these fields.

C.1 MASTER DATA BASE FIELDS.

For purposes of clarity the Master data base fields are shown on a single page in figure C-1.

C.2 MASTER DATA BASE GENERATION.

The Master data base is generated in a multi-step process. The processes are identified and described in what follows.

C.2.1 TRACK.FOX.

This is the same process identified and partially described in appendix B, section B.2.1.1. In addition to the identification and unpacking of the individual track files, it also appends data to the Master data base for each track. It fills in data fields 1 through 13: (1) session, (2) channel, (3) ACID, (4) user-type, (5) AC-type, (6) beacon code, (7) date, (8) start time, (9) stop time, (10) start altitude, (11) stop altitude, (12) target count, and (13) runway.

C.2.2 XYZT.FOX.

This process appends fields (14) min_x, (15) t_at_4_nmi (16) max_y_tntz, (17) xmaxy_tntz, (18) max_y_antz, (19) xmaxy_antz and (20) max_z, (21) min_z, (22) mean_y, (23) mean_xdot, (24) std_dev_y, (25) in_ntz, (26) ntz_dis, (27) x_at_vio to the Master data base.

--> Input: (ACID.RWY files [smoothed track files].

--> Process: Computes and merges data for fields 14 through 27 from tracks identified in Master data base.

--> Output: Modified Master data base fields cited above

Field	Field Name	Type	Lnth	Description
1	SESSION	Chr	8	Test name (S2131453) (see appendix A.1.1)
2	CH	Num	1	Channel # (0 or 1)
3	AC_ID	Chr	7	Aircraft ID (UAL9253)
4	USER_TYPE	Chr	1	User type (Military or Commercial or ...)
5	AC_TYPE	Chr	5	Aircraft type (B727)
6	BEACON	Chr	4	Beacon code (0000 thru 7777)
7	DATE	Date	8	Month/day/year
8	START_TIME	Chr	11	Time of day of first scan for track
9	STOP_TIME	Chr	11	Time of day of last scan for track
10	START_ALT	Num	6	Altitude of first scan for track
11	STOP_ALT	Num	6	Altitude of last scan for track
12	TARGET_CT	Num	4	Number of scans for track
13	RUNWAY	Chr	3	Runway being approached
14	MIN_X	Num	8	Minimum distance from threshold
15	T_AT_4_NMI	Chr	11	Time of day at 4 nmi from threshold
16	MAX_Y_TNTZ	Num	6	Maximum lateral deviation from ILS towards NTZ
17	XMAXY_TNTZ	Num	8	Distance from threshold at MAX_Y_TNTZ
18	MAX_Y_ANTZ	Num	6	Maximam lateral deviation from ILS away from NTZ
19	XMAXY_ANTZ	Num	8	Distance from threshold at MAX_Y_ANTZ
20	MAX_Z	Num	6	Maximum altitude for track
21	MIN_Z	Num	6	Minimum altitude for track
22	MEAN_Y	Num	6	Average ILS deviation from stabilization to TD
23	MEAN_XDOT	Num	8	Average velocity of A/C during ILS approach
24	STD_DEV_Y	Num	6	Standard deviation of ILS lateral deviation
25	IN_NTZ	Log	1	.TRUE. if A/C in NTZ after stabilization
26	NTZ_DIS	Num	6	Width of NOZ in feet
27	X_AT_VIO	Num	8	Distance from threshold at first NTZ violation
28	TEMP	Num	3	Temperature in degrees fahrenheit during track
29	DEWPT	Num	3	Dewpoint in degrees Fahrenheit during track
30	CEIL_TYPE	Chr	1	Ceiling type (M or E or W)
31	CEILING	Num	5	Ceiling height in feet
32	VISIBILITY	Num	5	Visibility in nautical miles
33	WEATHER	Chr	4	(Fog and/or Rain and/or Snow and/or ...)
34	WIND_SPEED	Num	2	Wind speed in knots
35	WIND_DIR	Num	3	Wind direction in degrees from true north
36	LLWAS_SPD	Num	2	Low level windshear alert system speed in knots
37	LLWAS_DIR	Num	3	Low level windshear alert system direction deg
38	LLWAS_GUST	Num	2	Low level windshear alert system gusts in knots
39	CFA_SPD	Num	2	Low level windshear alert system center field wind speed
40	CFA_DIR	Num	3	Low level windshear alert system center field wind direction
41	RVR	Num	4	Runway visual range in feet
42	BRMTR	Num	5	Barometric pressure in inches of mercury
43	STBL_X	Num	5	X at which A/C is stabilized on localizer
44	PAIR_LDR	Chr	7	Leading adjacent localizer AC_ID (if it exists)
45	PAIR_TRL	Chr	7	Trailing adjacent localizer AC_ID (if it exists)
46	GAP_START	Chr	11	Raw track file start time (as determined by GAP)
47	GAP_STOP	Chr	11	Raw track file stop time (as determined by GAP)
48	GAP_STRT_R	Num	6	Raw track file initial range
49	GAP_STOP_R	Num	6	Raw track file final range
50	GAP_NUM	Num	3	Number of scans in raw track file
51	GAP_MS_SCN	Num	3	Number of missing scans in raw track file
52	GAP_DOUBLE	Num	3	Number of double scans in raw track file
53	GAP_ALT	Num	3	Number of missing or unreasonable altitudes

Total of 282 bytes/record.

C.2.3 WX_APP.FOX.

This process will append fields (28) temperature, (29) dewpoint, (30) ceil_type, (31) ceiling, (32) visibility, (33) weather, (34) wind speed, and (35) wind direction to the Master data base.

--> Input: Weather data base.

--> Process: Merges fields from weather data base with the appropriate fields in the Master data base.

--> Output: Modifies Master data base weather fields cited above.

C.2.4 LWAS_MRG.FOX.

This process will append fields (36) LLWAS-speed, (37) LLWAS-direction, (38) LLWAS-wind gusts, (39) LLWAS Center field wind speed, and (40) LLWAS Center field wind direction.

--> Input: LLWAS data base for a session.

--> Process: Merges fields from an LLWAS data base selected by the user via session name with the appropriate fields in the Master data base.

--> Output: Modifies Master data base LLWAS fields cited above.

C.2.5 RCMS_MRG.FOX.

This process will append fields (41) Runway Visual Range and (42) barometer to the Master data base.

--> Input: RCMS data base for a session.

--> Process: Merges fields from an RCMS data base selected by the user via session name with the appropriate fields in the Master data base.

--> Output: Modifies Master data base RCMS fields cited above.

C.2.6 STABLE_X.FOX.

This process will append field (43) stbl_x to the Master data base.

--> Input: STABLE_X data base for a session.

--> Process: Merges stbl_x field from STABLE_X data base selected by user via session name with stbl_x field in the Master data base.

--> Output: Modifies Master data base stbl_X field.

C.2.7 GAPSTAT.FOX.

This process will append fields (46) gap_start, (47) gap_stop, (48) gap_strt_r, (49) gap_stop_r, (50) gap_num, (51) gap_ms_scn, (52) gap_double, and (53) gap_alt to the Master data base.

--> Input: $acid.rwy files.

--> Process: Extracts information from gap documentation files and merges it with Master data base fields cited above.

--> Output: Modifies Master data base GAP fields cited above.

APPENDIX D

ILS STABILITY ALGORITHMS

Two automatic algorithms, STABLE1 and STABLE2, were conceived to select the point at which the approaching aircraft is considered to be stabilized on the localizer portion of the ILS signal. This point is in terms of nautical miles (nmi) from runway threshold. The algorithm assumes that the input data file is the interpolated, smoothed, translated, corrected track file (see appendix A). The stabilization points produced by these algorthims were used to determine data of interest for Views 1, 2, and 3. View 1 was generated via STABLE1. View 2 was generated via STABLE2. View 3 was generated via STABLE2 with the additional constraint of deleting those tracks whose stabilization points were less than 10.5 miles from touchdown (see section 4 in the report for a description of the views).

STABLE1 and STABLE2 have been automated for the Chicago data reduction and analysis using Turbo C 2.0. Figures D-1 and D-2 provide pseudo code which should allow facile translation to code in a structured language. These figures use the following conventions:

a. Memory variables are in upper case.
b. Comments are enclosed in brackets (COMMENT).
c. Each line begins with the operation code to be performed.

```
do for each track
  sort track file on X descending
  Y = Y(first-X)
  do until (end-of-track)
    if Y < 500' then leave
            else load Y with Y(next-X)
  enddo
  STABLE1 = X
enddo
```

FIGURE D-1 STABLE1 ALGORITHM

```
LEVEL_FLIGHT=.false.
load first 21 altitudes into ZLIST (first 3 miles, 7 points/mile)
load first 21 x's into XLIST

Do until End_of_Data
  compute SLOPE1 (ZLIST(7)-ZLIST(1))/(XLIST(7)-XLIST(1))
  if SLOPE1 >= 1.5 then
    compute SLOPE2=(ZLIST(14)-ZLIST(7))/(XLIST(14)-XLIST(7))
    if SLOPE2 >= 1.5 then
      compute SLOPE3=(ZLIST(21)-ZLIST(14))/(XLIST(21)-XLIST(14))
      if SLOPE3 >= 1.5 then
        find MAX_Z from ZLIST(1) to ZLIST(14)
        let DESC_X = X(MAX_Z)
        leave
      else
        shift 1 segment (ZLIST(7),XLIST(7) movesto ZLIST(1),XLIST(1);
                         load next 7 points into ZLIST,XLIST)
      endif
    else
      shift 1 segment
    endif
  else
    shift 1 segment
    let LEVEL_FLIGHT=.true.
  endif
enddo

compute START_X            {the first x for which ABS(y)<=500'}
do for the next 21 x's           {3 miles}
  if y changes sign .and. y>1000' then         {this is considered an overshoot}
    recompute START_X            {the next x for which ABS(y)<=500'}
  endif
enddo

if .not. LEVEL_FLIGHT then
  let STABLE2 = START_X
else
  if START_X > DESC_X then
    let STABLE2 = (START_X + DESC_X)/2
    if y(STABLE2) > 500' then
      let CURRENT_X = (START_X + DESC_X)/2     {midpoint of [DESC_X,START_X]}
      let STABLE_X = DESC_X
      do until End_of_Data
        let CURRENT_X = NEXT_X      {next x in sequence closer to touchdown}
        if y(CURRENT_X) <= 500' then
          let STABLE2 = CURRENT_X
          leave {do loop}
        endif
      until CURRENT_X = DESC_X
    endif
  else              {START_X < DESC_X}
    let STABLE2 = START_X
  endif
endif
```

FIGURE D-2. STABLE2 ALGORITHM

APPENDIX E

SIMULTANEOUS ILS APPROACH PROCEDURES

5-126 SIMULTANEOUS ILS/MLS APPROACHES

TERMINAL

a. When parallel runways are at least 4,300 feet apart, authorize simultaneous ILS, MLS, or ILS and MLS approaches to parallel runways if:

(1) Straight-in landings will be made.

(2) ILS, MLS, radar, and appropriate frequencies are operating normally.

b. Prior to aircraft departing an outer fix, inform aircraft that simultaneous ILS/MLS approaches are in use. This information may be provided through the ATIS.

c. On the initial vector, inform the aircraft of tne ILS/MLS runway number and the localizer frequency or the MLS channel.

Phraseology:

I-L-S RUNWAY (runway number) (left/right). LOCALIZER FREQUENCY IS (frequency).

M-L-S RUNWAY (runway number)(left/right). M-L-S CHANNEL IS (channel).

d. Clear the aircraft to descend to the appropriate glideslope/glidepath intercept altitude soon enough to provide a period of level flight to dissipate excess speed. Provide at least 1 mile of straight flight prior to the final approach course intercept.

5-126d Note. — Not applicable to curved and segmented MLS approaches.

e. Vector the aircraft to intercept the final approach course at an angle not greater than 30 degrees.

f. Provide a minimum of 1,000 feet vertical or a minimum of 3 miles radar separation between aircraft during turn-on to parallel final approach courses. Provide a minimum of 3 miles radar separation between aircraft on the same final approach course.

5-126f Note. — Aircraft established on a final approach course are separated from aircraft established on an adjacent parallel final approach course provided neither aircraft penetrates the depicted NTZ.

g. When assigning the final heading to intercept the final approach course, issue the following to the aircraft:

(1) Position from a fix on the localizer course or the MLS azimuth course.

(2) An altitude to maintain until established on the localizer course or the MLS azimuth course.

5-126g(2) Reference. — Arrival Instructions, 5-128.

(3) Clearance for the appropriate ILS/MLS runway number approach.

Phraseology:

POSITION (number) MILES FROM (fix). TURN (left/right) HEADING (degrees). MAINTAIN (altitude) UNTIL ESTABLISHED ON THE LOCALIZER. CLEARED FOR I-L-S RUNWAY (number)(left/right) APPROACH.

POSITION (number) MILES FROM (fix). TURN (left/right) HEADING (degrees). MAINTAIN (altitude) UNTIL ESTABLISHED ON THE FINAL APPROACH COURSE. CLEARED FOR M-L-S RUNWAY (number)(left/right) APPROACH.

h. Monitor all approaches regardless of weather. Monitor local control frequency to receive any aircraft transmission. Issue control instructions and information necessary to ensure separation between aircraft and to ensure aircraft do not enter the "no transgression zone" (NTZ).

5-126h Note 1. — Separate monitor controllers, each with transmit/receive and override capability on the local control frequency, shall ensure aircraft do not penetrate the depicted NTZ. Facility directives shall delineate responsibility for providing a minimum of 3 miles longitudinal separation between aircraft on the same final approach course.

5-126h Note 2. — An NTZ at least 2,000 feet wide is established equidistant between runway centerlines extended and is depicted on the monitor display. The primary responsibility for navigation on the final approach course rests with the pilot. Therefore, control instructions and information are issued only to ensure separation between aircraft and that aircraft do not penetrate the NTZ. Pilots are not expected to acknowledge those transmissions unless specifically requested to do so.

5-126h Note 3. — For the purposes of ensuring an aircraft does not penetrate the NTZ, the "aircraft" is considered the center of the primary radar return for that aircraft. The provisions of paragraph 5-71 apply also.

(1) When aircraft are observed to overshoot the turn-on or to continue on a track which will penetrate the NTZ, instruct the aircraft to return to the correct final approach course immediately.

Phraseology:

YOU HAVE CROSSED THE FINAL APPROACH COURSE. TURN (left/right) IMMEDIATELY AND RETURN TO LOCALIZER/AZIMUTH COURSE,

or

TURN (left/right) AND RETURN TO LOCALIZER/AZIMUTH COURSE.

(2) When an aircraft is observed penetrating the NTZ, instruct aircraft on the adjacent final approach course to alter course to avoid the deviating aircraft.

Phraseology:

TURN (left/right) HEADING (degrees) IMMEDIATELY, CLIMB AND MAINTAIN (altitude).

(3) Terminate radar monitoring when one of the following occurs:

(a) Visual separation is applied.

(b) The aircraft reports the approach lights or runway in sight.

(c) The aircraft is 1 mile or less from the runway threshold, if procedurally required and contained in facility directives.

(4) Do not inform the aircraft when radar monitoring is terminated.

(5) Do not apply the provisions of paragraph 5-180 for simultaneous ILS, MLS, or ILS and MLS approaches.

i. When simultaneous ILS, MLS, or ILS and MLS approaches are being conducted to parallel runways, consideration should be given to known factors that may in any way affect the safety of the instrument approach phase of flight, such as surface wind direction and velocity, wind shear alerts/reports, severe weather activity, etc. Closely monitor weather activity that could impact the final approach course. Weather conditions in the vicinity of the final approach course may dictate a change of approach in use.

5-127 thru 5-129 RESERVED

Change

Reprinted from Air Traffic Control Order 7110.65E (1)

Appendix F

STATISTICAL TABLES

LIST OF TABLES

LIST OF TABLES (CON'T)

TABLE 1

MEASURED DEVIATION FROM EXTENDED RUNWAY CENTERLINE

VIEW 1 3197 AIRCRAFT

	AWAY FROM NTZ		TOWARD NTZ		TOTAL OBSERVATIONS		
RANGE	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	STANDARD DEVIATION
15.00	136	-217	106	208	242	-31	250
14.85	757	-209	559	220	1316	-27	257
14.70	793	-215	609	242	1402	-17	282
14.55	823	-231	679	259	1502	-9	313
14.40	849	-239	739	274	1588	0	345
14.25	861	-240	801	293	1662	17	383
14.10	866	-247	869	307	1735	31	422
13.95	902	-252	916	322	1818	37	454
13.80	967	-255	951	332	1918	36	477
13.65	1011	-251	990	335	2001	39	491
13.50	1036	-251	1030	334	2066	41	501
13.35	1083	-252	1052	342	2135	40	508
13.20	1125	-251	1060	348	2185	40	511
13.05	1164	-255	1080	351	2244	37	512
12.90	1207	-252	1089	354	2296	36	509
12.75	1244	-250	1104	352	2348	33	504
12.60	1276	-249	1126	341	2402	27	495
12.45	1302	-240	1136	332	2438	27	481
12.30	1300	-237	1172	316	2472	25	465
12.15	1338	-224	1172	312	2510	26	449
12.00	1340	-220	1208	298	2548	25	433
11.85	1297	-222	1280	278	2577	27	419
11.70	1306	-219	1296	272	2602	26	407
11.55	1320	-223	1316	262	2636	19	396
11.40	1354	-226	1319	252	2673	10	386
11.25	1394	-226	1310	245	2704	3	377
11.10	1427	-225	1301	237	2728	-5	369
10.95	1492	-219	1261	238	2753	-10	363
10.80	1499	-222	1280	229	2779	-14	356
10.65	1503	-220	1300	221	2803	-15	348
10.50	1523	-213	1304	217	2827	-15	341
10.35	1522	-210	1324	213	2846	-13	338
10.20	1521	-207	1339	211	2860	-11	335
10.05	1523	-200	1351	206	2874	-9	331
9.90	1516	-194	1374	199	2890	-7	325
9.75	1517	-187	1390	195	2907	-4	319
9.60	1518	-183	1402	189	2920	-4	315
9.45	1521	-180	1415	183	2936	-5	311
9.30	1487	-182	1467	176	2954	-4	307
9.15	1460	-186	1508	168	2968	-6	302
9.00	1483	-181	1496	169	2979	-5	294
8.85	1461	-181	1529	166	2990	-4	287
8.70	1492	-176	1511	166	3003	-4	280
8.55	1512	-173	1501	165	3013	-5	273
8.40	1516	-173	1505	165	3021	-5	269
8.25	1525	-174	1514	167	3039	-4	265
8.10	1529	-171	1524	167	3053	-3	261
7.95	1529	-166	1532	167	3061	1	256
7.80	1524	-161	1548	167	3072	4	250
7.65	1507	-157	1576	163	3083	7	243

TABLE 1 (continued)

MEASURED DEVIATION FROM EXTENDED RUNWAY CENTERLINE

VIEW 1 3197 AIRCRAFT

	AWAY FROM NTZ		TOWARD NTZ		TOTAL OBSERVATIONS		
RANGE	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	STANDARD DEVIATION
7.50	1496	-150	1593	160	3089	10	236
7.35	1497	-142	1599	158	3096	13	230
7.20	1468	-139	1634	153	3102	15	223
7.05	1467	-137	1643	150	3110	15	216
6.90	1478	-136	1646	147	3124	13	210
6.75	1492	-134	1642	144	3134	12	203
6.60	1513	-131	1627	143	3140	11	197
6.45	1563	-127	1583	141	3146	8	191
6.30	1570	-125	1584	136	3154	6	185
6.15	1604	-120	1554	132	3158	4	178
6.00	1611	-116	1553	127	3164	3	172
5.85	1615	-113	1552	122	3167	2	168
5.70	1606	-114	1565	119	3171	1	168
5.55	1608	-115	1568	117	3176	0	169
5.40	1601	-118	1582	116	3183	-2	170
5.25	1621	-117	1563	117	3184	-2	171
5.10	1629	-118	1559	119	3188	-2	171
4.95	1632	-117	1556	120	3188	-2	171
4.80	1630	-117	1559	120	3189	-1	171
4.65	1647	-116	1542	121	3189	-1	169
4.50	1648	-115	1541	119	3189	-2	166
4.35	1655	-113	1535	116	3190	-3	162
4.20	1686	-108	1502	113	3188	-4	157
4.05	1681	-107	1505	107	3186	-6	152
3.90	1688	-104	1494	102	3182	-7	145
3.75	1707	-101	1473	99	3180	-8	140
3.60	1738	-97	1443	97	3181	-9	135
3.45	1754	-94	1427	94	3181	-10	131
3.30	1757	-92	1424	91	3181	-10	127
3.15	1758	-90	1423	89	3181	-10	124
3.00	1749	-88	1432	87	3181	-9	121
2.85	1720	-89	1459	84	3179	-9	119
2.70	1750	-86	1428	82	3178	-11	115
2.55	1802	-83	1373	79	3175	-13	109
2.40	1820	-81	1332	74	3152	-15	104
2.25	1807	-77	1293	72	3100	-15	100
2.10	1747	-74	1225	71	2972	-15	96
1.95	1696	-75	1173	68	2869	-17	94
1.80	1699	-75	1142	65	2841	-19	93
1.65	1726	-75	1044	62	2770	-23	89
1.50	1700	-76	931	60	2631	-28	87
1.35	1530	-73	797	57	2327	-29	82
1.20	1393	-71	610	50	2003	-34	75
1.05	1349	-68	590	42	1939	-35	69
0.90	1342	-64	574	39	1916	-33	65
0.75	1330	-62	565	37	1895	-32	61
0.60	1319	-60	545	34	1864	-33	59
0.45	1219	-60	557	30	1776	-32	60
0.30	1070	-57	566	28	1636	-28	59
0.15	981	-53	565	29	1546	-23	59

TABLE 2

MEASURED DEVIATION FROM EXTENDED RUNWAY CENTERLINE

VIEW 2

3197 AIRCRAFT

	AWAY FROM NTZ		TOWARD NTZ		TOTAL OBSERVATIONS		
RANGE	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	STANDARD DEVIATION
15.00	23	-184	16	128	39	-56	199
14.85	121	-173	80	161	201	-40	204
14.70	131	-168	77	180	208	-39	210
14.55	125	-185	88	187	213	-31	235
14.40	125	-198	94	190	219	-31	259
14.25	130	-217	105	194	235	-33	283
14.10	139	-233	106	223	245	-36	314
13.95	169	-244	119	267	288	-33	405
13.80	278	-223	198	245	476	-29	380
13.65	338	-218	261	222	599	-27	359
13.50	406	-206	311	225	717	-19	347
13.35	520	-203	396	215	916	-22	329
13.20	556	-205	430	210	986	-24	323
13.05	584	-203	431	224	1015	-21	323
12.90	622	-202	454	237	1076	-17	335
12.75	672	-210	494	251	1166	-15	352
12.60	705	-208	531	248	1236	-12	345
12.45	736	-200	567	243	1303	-7	331
12.30	756	-196	589	234	1345	-8	317
12.15	943	-187	729	218	1672	-10	293
12.00	1000	-186	831	215	1831	-4	287
11.85	1015	-195	936	201	1951	-5	284
11.70	1100	-206	1007	203	2107	-11	298
11.55	1113	-208	1037	196	2150	-13	289
11.40	1145	-207	1073	191	2218	-15	281
11.25	1216	-206	1099	184	2315	-21	274
11.10	1272	-206	1106	179	2378	-27	269
10.95	1342	-201	1086	181	2428	-30	265
10.80	1343	-204	1120	176	2463	-31	260
10.65	1363	-202	1161	173	2524	-30	253
10.50	1419	-195	1186	174	2605	-27	251
10.35	1436	-194	1213	174	2649	-25	250
10.20	1440	-191	1240	174	2680	-22	248
10.05	1447	-185	1261	170	2708	-20	245
9.90	1458	-179	1281	167	2739	-17	242
9.75	1474	-173	1306	165	2780	-14	238
9.60	1488	-172	1328	163	2816	-14	239
9.45	1490	-170	1350	161	2840	-13	237
9.30	1456	-171	1401	155	2857	-11	234
9.15	1436	-174	1440	149	2876	-12	231
9.00	1465	-171	1434	151	2899	-12	230
8.85	1438	-171	1475	149	2913	-9	228
8.70	1475	-169	1460	150	2935	-10	227
8.55	1498	-167	1452	150	2950	-11	223
8.40	1508	-167	1457	150	2965	-12	219
8.25	1516	-168	1472	152	2988	-10	218
8.10	1516	-166	1485	152	3001	-9	216
7.95	1514	-162	1499	152	3013	-5	213
7.80	1507	-150	1513	152	3020	-1	208
7.65	1490	-152	1546	150	3036	2	203

TABLE 2 (continued)

MEASURED DEVIATION FROM EXTENDED RUNWAY CENTERLINE

VIEW 2

3197 AIRCRAFT

	AWAY FROM NTZ		TOWARD NTZ		TOTAL OBSERVATIONS		
RANGE	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	STANDARD DEVIATION
7.50	1480	-147	1568	148	3048	5	200
7.35	1482	-139	1578	147	3060	8	197
7.20	1456	-136	1612	142	3068	10	193
7.05	1458	-135	1620	140	3078	10	191
6.90	1468	-134	1630	138	3098	9	189
6.75	1483	-134	1626	137	3109	8	186
6.60	1506	-130	1613	136	3119	7	182
6.45	1554	-126	1573	136	3127	6	179
6.30	1562	-124	1572	131	3134	4	176
6.15	1598	-119	1545	128	3143	2	171
6.00	1607	-116	1548	125	3155	2	168
5.85	1612	-113	1548	120	3160	1	163
5.70	1602	-114	1561	117	3163	0	162
5.55	1607	-115	1565	115	3172	-1	163
5.40	1598	-117	1579	114	3177	-3	163
5.25	1619	-117	1560	115	3179	-3	163
5.10	1627	-117	1555	116	3182	-3	164
4.95	1630	-117	1553	117	3183	-2	164
4.80	1628	-117	1556	118	3184	-2	164
4.65	1645	-115	1541	119	3186	-2	163
4.50	1647	-115	1540	118	3187	-3	160
4.35	1654	-113	1534	114	3188	-3	157
4.20	1685	-108	1501	112	3186	-5	153
4.05	1680	-107	1504	106	3184	-6	148
3.90	1687	-104	1493	101	3180	-8	142
3.75	1708	-101	1472	98	3180	-9	137
3.60	1738	-97	1442	96	3180	-10	133
3.45	1754	-94	1426	93	3180	-10	129
3.30	1757	-92	1423	90	3180	-10	126
3.15	1758	-90	1422	88	3180	-10	123
3.00	1749	-88	1431	86	3180	-10	120
2.85	1720	-89	1458	83	3178	-10	117
2.70	1750	-86	1427	81	3177	-11	113
2.55	1802	-83	1372	78	3174	-13	108
2.40	1820	-81	1331	74	3151	-15	103
2.25	1807	-77	1292	71	3099	-15	98
2.10	1747	-74	1224	70	2971	-15	95
1.95	1696	-75	1172	67	2868	-17	93
1.80	1699	-75	1141	64	2840	-19	92
1.65	1726	-75	1044	62	2770	-23	89
1.50	1700	-76	931	60	2631	-28	87
1.35	1530	-73	797	57	2327	-29	82
1.20	1393	-71	610	50	2003	-34	75
1.05	1349	-68	590	42	1939	-35	69
0.90	1342	-64	574	39	1916	-33	65
0.75	1330	-62	565	37	1895	-32	61
0.60	1319	-60	545	34	1864	-33	59
0.45	1219	-60	557	30	1776	-32	60
0.30	1070	-57	566	28	1636	-28	59
0.15	981	-53	565	29	1546	-23	59

TABLE 3

MEASURED DEVIATION FROM EXTENDED RUNWAY CENTERLINE

VIEW 3 2585 AIRCRAFT

	AWAY FROM NTZ		TOWARD NTZ		TOTAL OBSERVATIONS		
RANGE	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	STANDARD DEVIATION
15.00	23	-184	16	128	39	-56	199
14.85	121	-173	80	161	201	-40	204
14.70	131	-168	77	180	208	-39	210
14.55	125	-185	88	187	213	-31	235
14.40	125	-198	94	190	219	-31	259
14.25	130	-217	105	194	235	-33	283
14.10	139	-233	106	223	245	-36	314
13.95	169	-244	119	267	288	-33	405
13.80	278	-223	198	245	476	-29	380
13.65	338	-218	261	222	599	-27	359
13.50	406	-206	311	225	717	-19	347
13.35	520	-203	396	215	916	-22	329
13.20	556	-205	430	210	986	-24	323
13.05	584	-203	431	224	1015	-21	323
12.90	622	-202	454	237	1076	-17	335
12.75	672	-210	494	251	1166	-15	352
12.60	705	-208	531	248	1236	-12	345
12.45	736	-200	567	243	1303	-7	331
12.30	756	-196	589	234	1345	-8	317
12.15	943	-187	729	218	1672	-10	293
12.00	1000	-186	831	215	1831	-4	287
11.85	1015	-195	936	201	1951	-5	284
11.70	1100	-206	1007	203	2107	-11	298
11.55	1113	-208	1037	196	2150	-13	289
11.40	1145	-207	1073	191	2218	-15	281
11.25	1216	-206	1099	184	2315	-21	274
11.10	1272	-206	1106	179	2378	-27	269
10.95	1342	-201	1086	181	2428	-30	265
10.80	1343	-204	1120	176	2463	-31	260
10.65	1363	-202	1161	173	2524	-30	253
10.50	1408	-196	1177	174	2585	-28	252
10.35	1401	-193	1184	172	2585	-26	249
10.20	1396	-189	1189	171	2585	-24	246
10.05	1395	-183	1190	167	2585	-22	242
9.90	1382	-176	1203	163	2585	-19	238
9.75	1374	-169	1211	159	2585	-16	233
9.60	1380	-163	1205	155	2585	-15	228
9.45	1367	-161	1218	151	2585	-14	225
9.30	1327	-163	1258	145	2585	-13	223
9.15	1304	-165	1281	140	2585	-14	220
9.00	1326	-161	1259	142	2585	-13	218
8.85	1298	-162	1287	139	2585	-12	215
8.70	1315	-157	1270	141	2585	-11	212
8.55	1314	-157	1271	141	2585	-10	208
8.40	1316	-157	1269	141	2585	-11	206
8.25	1313	-157	1272	143	2585	-10	204
8.10	1308	-155	1277	143	2585	-8	203
7.95	1305	-151	1280	145	2585	-4	200
7.80	1299	-146	1286	146	2585	-1	197
7.65	1284	-141	1301	142	2585	1	191

TABLE 3 (continued)

MEASURED DEVIATION FROM EXTENDED RUNWAY CENTERLINE

VIEW 3 2585 AIRCRAFT

RANGE	AWAY FROM NTZ SAMPLE SIZE	AWAY FROM NTZ MEAN	TOWARD NTZ SAMPLE SIZE	TOWARD NTZ MEAN	TOTAL OBSERVATIONS SAMPLE SIZE	TOTAL OBSERVATIONS MEAN	TOTAL OBSERVATIONS STANDARD DEVIATION
7.50	1265	-136	1320	138	2585	4	185
7.35	1262	-128	1323	136	2585	7	180
7.20	1221	-126	1364	131	2585	10	176
7.05	1219	-123	1366	131	2585	11	174
6.90	1217	-123	1368	129	2585	10	172
6.75	1235	-121	1350	129	2585	9	170
6.60	1262	-120	1323	128	2585	7	167
6.45	1294	-117	1291	126	2585	5	165
6.30	1303	-115	1282	123	2585	3	162
6.15	1331	-110	1254	119	2585	1	157
6.00	1337	-107	1248	114	2585	-1	152
5.85	1340	-105	1245	109	2585	-2	148
5.70	1334	-106	1251	105	2585	-4	146
5.55	1339	-107	1246	103	2585	-6	145
5.40	1330	-109	1255	101	2585	-7	145
5.25	1357	-110	1228	103	2585	-8	146
5.10	1366	-111	1219	104	2585	-10	146
4.95	1369	-111	1216	103	2585	-10	145
4.80	1382	-111	1203	104	2585	-11	145
4.65	1398	-110	1186	106	2584	-11	144
4.50	1400	-109	1183	105	2583	-11	142
4.35	1408	-108	1174	102	2582	-12	140
4.20	1442	-103	1139	101	2581	-13	137
4.05	1439	-102	1140	97	2579	-14	134
3.90	1448	-99	1127	93	2575	-15	130
3.75	1456	-96	1117	90	2573	-15	126
3.60	1469	-94	1103	89	2572	-15	122
3.45	1465	-92	1106	86	2571	-15	118
3.30	1457	-90	1113	83	2570	-15	115
3.15	1464	-88	1106	82	2570	-15	114
3.00	1462	-86	1108	81	2570	-14	112
2.85	1444	-87	1124	79	2568	-14	111
2.70	1470	-85	1097	77	2567	-15	108
2.55	1508	-82	1057	73	2565	-18	103
2.40	1526	-80	1022	69	2548	-21	98
2.25	1507	-77	995	67	2502	-20	94
2.10	1445	-74	943	65	2388	-19	90
1.95	1401	-75	905	63	2306	-21	88
1.80	1399	-75	882	61	2281	-22	87
1.65	1416	-75	809	58	2225	-27	85
1.50	1392	-76	724	56	2116	-31	84
1.35	1249	-73	614	53	1863	-32	79
1.20	1142	-71	467	47	1609	-37	74
1.05	1110	-69	462	41	1572	-37	68
0.90	1117	-64	434	38	1551	-36	63
0.75	1106	-62	424	36	1530	-35	59
0.60	1094	-61	407	33	1501	-35	58
0.45	998	-61	421	29	1419	-34	57
0.30	862	-58	426	28	1288	-30	57
0.15	780	-54	427	30	1207	-24	58

TABLE 4
OBSERVED DEVIATIONS FROM LOCALIZER CENTERLINE

TIME PERIOD: 1/24/89 TO 3/20/89 VIEW 1 3197 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT AWAY FROM NTZ -900	-800	-700	-650	-600	-550	-500		NUMBER OF AIRCRAFT TOWARD NTZ 500	550	600	650	700	800	900
10.50	2827	19	14	13	9	12	19	37	2592	27	14	14	8	11	11	27
10.35	2846	19	12	17	2	18	10	28	2637	21	14	11	10	11	12	24
10.20	2860	18	8	19	5	14	9	28	2653	22	12	16	9	15	12	20
10.05	2874	22	3	16	12	16	11	15	2670	22	19	14	7	19	7	21
9.90	2890	22	5	12	15	6	10	17	2688	28	14	20	7	19	6	21
9.75	2907	23	8	5	11	9	11	18	2713	21	22	19	8	10	7	22
9.60	2920	22	8	6	7	14	13	11	2737	25	21	13	9	5	6	23
9.45	2936	20	7	8	13	7	16	19	2753	16	19	16	6	8	6	22
9.30	2954	22	3	6	11	8	21	17	2779	14	16	15	5	13	2	22
9.15	2968	18	7	5	7	11	14	24	2801	21	10	10	6	10	7	17
9.00	2979	18	5	6	6	9	19	11	2827	17	13	11	6	7	8	16
8.85	2990	15	2	14	4	10	12	15	2850	11	10	6	5	11	5	20
8.70	3003	13	6	8	1	11	22	13	2860	8	7	7	8	14	6	19
8.55	3013	14	4	10	3	6	13	17	2881	11	3	9	8	10	6	18
8.40	3021	13	6	4	4	7	9	14	2905	12	3	6	7	10	5	16
8.25	3039	11	6	4	6	7	9	17	2927	8	6	3	7	10	4	14
8.10	3053	10	5	4	2	10	10	15	2938	11	8	7	6	9	3	15
7.95	3061	10	4	6	1	7	11	22	2939	15	7	8	8	5	4	14
7.80	3072	10	4	6	1	13	7	7	2968	10	13	7	4	6	2	14
7.65	3083	5	7	6	3	10	8	10	2983	12	5	8	7	3	5	11
7.50	3089	4	8	5	4	9	9	12	2987	11	6	6	4	6	6	12
7.35	3096	4	5	6	6	5	12	5	3005	9	6	3	2	9	5	14
7.20	3102	4	1	7	5	5	11	8	3014	7	10	2	3	4	7	14
7.05	3110	3	2	5	6	5	6	10	3028	10	4	4	1	6	8	12
6.90	3124	3	2	3	7	6	5	6	3052	8	4	1	3	6	8	10
6.75	3134	1	1	6	4	7	3	10	3061	5	8	4	4	6	5	9
6.60	3140	0	2	4	7	3	4	5	3075	7	8	2	5	6	4	8
6.45	3146	0	0	3	5	8	4	3	3087	7	4	4	5	6	5	5
6.30	3154	0	0	2	3	5	8	7	3093	8	4	4	6	7	3	4
6.15	3158	0	1	0	4	5	7	6	3101	9	8	3	3	4	3	4
6.00	3164	0	2	1	3	3	4	11	3108	8	6	5	3	4	3	3
5.85	3167	1	1	3	1	3	2	7	3121	5	8	4	3	3	2	3
5.70	3171	1	0	4	2	2	3	4	3128	6	11	1	1	3	0	5
5.55	3176	1	0	2	4	2	4	7	3129	12	6	2	1	1	0	5
5.40	3183	1	1	2	0	3	6	3	3142	11	4	3	1	0	2	4
5.25	3184	1	1	2	2	2	3	5	3142	11	4	3	1	1	1	5
5.10	3188	2	1	2	2	3	2	5	3146	5	8	5	0	0	3	4
4.95	3188	2	1	3	4	0	5	3	3143	9	3	4	5	2	1	3
4.80	3189	2	1	5	2	3	2	5	3145	5	5	1	7	3	0	3
4.65	3189	1	0	5	4	3	2	6	3144	7	3	1	5	4	1	3
4.50	3189	1	0	3	2	6	3	4	3147	5	3	4	3	4	0	4
4.35	3190	1	0	2	1	5	6	2	3153	5	3	1	3	2	2	4
4.20	3188	0	1	1	2	4	5	7	3149	3	5	2	1	3	2	3
4.05	3186	0	0	3	3	4	3	6	3151	3	4	2	1	2	1	3
3.90	3182	0	0	1	3	5	4	3	3154	3	2	1	1	0	2	3
3.75	3180	0	0	1	4	1	2	4	3158	3	1	0	2	0	1	3
3.60	3181	0	0	3	1	1	1	1	3165	2	1	0	2	1	0	3
3.45	3181	0	0	2	1	1	0	4	3162	4	0	2	2	0	0	3
3.30	3181	0	0	1	3	3	0	0	3164	2	2	2	1	0	0	3
3.15	3181	0	2	1	0	0	3	1	3165	3	1	2	0	0	1	2
3.00	3181	1	1	1	0	0	0	3	3168	2	0	2	0	1	0	2
2.85	3179	1	0	2	0	0	1	0	3168	2	0	2	0	1	1	1
2.70	3178	0	1	0	1	1	1	1	3166	2	0	2	2	0	0	1
2.55	3175	0	0	1	0	0	1	2	3165	1	3	1	0	0	0	1
2.40	3152	0	0	0	0	0	2	0	3145	2	2	0	0	0	0	1
2.25	3100	0	0	0	0	0	1	0	3097	0	1	0	0	0	0	1
2.10	2972	0	0	0	0	0	0	1	2969	0	1	0	0	0	0	1
1.95	2869	0	0	0	0	0	0	1	2865	0	2	0	0	0	1	0
1.80	2841	0	0	0	0	0	1	1	2837	0	1	0	0	1	0	0
1.65	2770	0	0	0	0	0	0	1	2767	1	1	0	0	0	0	0
1.50	2631	0	0	0	0	0	0	1	2630	0	0	0	0	0	0	0
1.35	2327	0	0	0	0	0	0	1	2326	0	0	0	0	0	0	0
1.20	2003	0	0	0	0	0	0	0	2003	0	0	0	0	0	0	0
1.05	1939	0	0	0	0	0	0	0	1939	0	0	0	0	0	0	0
0.90	1916	0	0	0	0	0	0	0	1916	0	0	0	0	0	0	0
0.75	1895	0	0	0	0	0	0	0	1895	0	0	0	0	0	0	0
0.60	1864	0	0	0	0	0	0	1	1863	0	0	0	0	0	0	0
0.45	1776	0	0	0	0	0	1	0	1775	0	0	0	0	0	0	0

TABLE 5
OBSERVED DEVIATIONS FROM LOCALIZER CENTERLINE
VIEW 2

TIME PERIOD: 1/24/89 TO 3/20/89 — 3197 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT AWAY FROM NTZ -900	-800	-700	-650	-600	-550	-500		NUMBER OF AIRCRAFT TOWARD NTZ 500	550	600	650	700	800	900
10.50	2605	10	6	10	9	12	14	33	2461	14	10	9	3	6	6	2
10.35	2649	9	9	13	2	16	9	26	2517	16	7	7	5	7	5	1
10.20	2680	10	5	16	4	12	8	23	2547	19	9	10	7	7	2	1
10.05	2708	13	2	15	10	13	12	13	2573	16	15	11	6	6	1	2
9.90	2739	11	6	11	13	6	9	16	2605	23	9	13	3	10	2	2
9.75	2780	12	7	7	10	7	11	17	2646	17	15	14	7	4	3	3
9.60	2816	13	7	6	10	18	13	12	2674	19	19	8	6	3	2	6
9.45	2840	11	8	6	13	8	19	20	2694	14	14	14	4	6	3	6
9.30	2857	13	3	7	10	8	22	19	2717	12	16	9	4	9	1	7
9.15	2876	10	6	4	10	9	15	24	2746	18	9	5	5	7	3	5
9.00	2899	10	4	7	5	10	20	10	2785	13	8	9	4	4	5	5
8.85	2913	8	3	12	3	11	13	14	2808	7	8	6	2	6	5	7
8.70	2935	8	4	8	1	13	21	14	2824	5	6	6	4	8	5	8
8.55	2950	9	4	9	2	9	16	17	2845	8	1	6	6	8	3	7
8.40	2965	8	6	4	4	7	13	15	2872	9	2	4	4	8	4	5
8.25	2988	7	5	4	7	7	10	18	2898	7	4	2	7	5	3	4
8.10	3001	6	5	3	2	11	12	15	2910	10	7	5	5	5	1	4
7.95	3013	6	4	6	1	8	12	24	2911	14	7	7	5	2	2	4
7.80	3020	7	3	6	1	13	7	8	2938	9	12	5	2	4	2	3
7.65	3036	3	6	6	2	9	8	10	2959	11	2	8	4	3	3	2
7.50	3048	2	8	5	3	9	9	12	2965	10	4	5	3	6	5	2
7.35	3060	2	5	6	5	5	12	6	2985	8	6	3	0	9	5	3
7.20	3068	2	1	7	4	5	11	8	2995	7	10	2	2	3	7	4
7.05	3078	2	2	5	6	5	6	10	3009	10	3	4	1	4	7	4
6.90	3098	2	2	3	7	6	5	6	3037	8	4	1	3	5	7	2
6.75	3109	1	1	7	5	7	3	10	3044	5	7	4	4	5	4	2
6.60	3119	0	2	4	7	3	5	4	3062	7	8	3	5	5	2	2
6.45	3127	0	0	3	5	8	3	3	3076	7	5	4	4	5	3	1
6.30	3134	0	0	2	3	5	7	7	3082	8	4	3	4	6	2	1
6.15	3143	0	1	0	4	5	7	6	3092	8	8	3	2	4	3	0
6.00	3155	0	2	2	3	2	4	12	3101	8	6	5	3	4	3	0
5.85	3160	1	1	3	1	2	2	8	3118	5	8	3	3	3	1	1
5.70	3163	1	0	4	2	1	3	4	3125	6	11	1	0	3	0	2
5.55	3172	1	0	3	4	2	4	7	3126	12	6	2	2	1	0	2
5.40	3177	1	1	2	0	3	5	3	3140	11	4	3	1	0	2	1
5.25	3179	1	1	2	1	2	2	5	3142	11	4	3	1	1	1	2
5.10	3182	1	1	2	2	3	2	5	3144	5	8	5	0	0	2	2
4.95	3183	1	1	3	4	0	5	3	3141	9	3	4	5	1	1	2
4.80	3184	1	1	5	2	3	2	5	3143	4	5	1	7	3	0	2
4.65	3186	1	0	4	4	3	2	6	3143	7	3	1	5	4	1	2
4.50	3187	1	0	3	2	6	3	4	3146	5	3	4	3	4	0	3
4.35	3188	1	0	2	1	5	6	2	3152	5	3	1	3	2	2	3
4.20	3186	0	1	1	2	4	5	7	3148	3	5	2	1	3	2	2
4.05	3184	0	0	3	3	4	3	6	3150	3	4	2	1	2	1	2
3.90	3180	0	0	1	3	5	4	3	3153	3	2	1	1	0	2	2
3.75	3180	0	0	1	4	1	2	5	3158	3	1	0	2	0	1	2
3.60	3180	0	0	3	1	1	1	1	3165	2	1	0	2	1	0	2
3.45	3180	0	0	2	1	1	0	4	3162	4	0	2	2	0	0	2
3.30	3180	0	0	1	3	3	0	0	3164	2	2	2	1	0	0	2
3.15	3180	0	2	1	0	0	3	1	3165	3	1	2	0	0	1	1
3.00	3180	1	1	1	0	0	0	3	3168	2	0	2	0	1	0	1
2.85	3178	1	0	2	0	0	1	0	3168	2	0	2	0	1	1	0
2.70	3177	0	1	0	1	1	1	1	3166	2	0	2	2	0	0	0
2.55	3174	0	0	1	0	0	1	2	3165	1	3	1	0	0	0	0
2.40	3151	0	0	0	0	0	2	0	3145	2	2	0	0	0	0	0
2.25	3099	0	0	0	0	0	1	0	3097	0	1	0	0	0	0	0
2.10	2971	0	0	0	0	0	0	1	2969	0	1	0	0	0	0	0
1.95	2868	0	0	0	0	0	0	1	2865	0	2	0	0	0	0	0
1.80	2840	0	0	0	0	0	1	1	2837	0	1	0	0	0	0	0
1.65	2770	0	0	0	0	0	0	1	2767	1	1	0	0	0	0	0
1.50	2631	0	0	0	0	0	0	1	2630	0	0	0	0	0	0	0
1.35	2327	0	0	0	0	0	0	1	2326	0	0	0	0	0	0	0
1.20	2003	0	0	0	0	0	0	0	2003	0	0	0	0	0	0	0
1.05	1939	0	0	0	0	0	0	0	1939	0	0	0	0	0	0	0
0.90	1916	0	0	0	0	0	0	0	1916	0	0	0	0	0	0	0
0.75	1895	0	0	0	0	0	0	0	1895	0	0	0	0	0	0	0
0.60	1864	0	0	0	0	0	0	1	1863	0	0	0	0	0	0	0
0.45	1776	0	0	0	0	0	1	0	1775	0	0	0	0	0	0	0

TABLE 6
OBSERVED DEVIATIONS FROM LOCALIZER CENTERLINE

TIME PERIOD: 1/24/89 TO 3/20/89 VIEW 3 2595 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT AWAY FROM NTZ -900	-800	-700	-650	-600	-550	-500		NUMBER OF AIRCRAFT TOWARD NTZ 500	550	600	650	700	800	900
10.50	2585	10	6	10	9	12	14	33	2441	14	10	9	3	6	6	2
10.35	2585	9	9	12	2	16	9	26	2455	16	7	7	5	7	4	1
10.20	2585	10	5	15	4	12	7	23	2457	17	9	10	7	6	2	1
10.05	2585	13	2	12	10	13	11	13	2456	16	15	10	6	5	1	2
9.90	2585	11	5	10	12	6	8	15	2457	23	9	13	3	10	1	2
9.75	2585	11	7	5	9	7	10	15	2462	17	14	13	6	4	3	2
9.60	2585	10	7	5	5	12	12	10	2472	15	17	7	5	2	2	4
9.45	2585	9	7	6	10	6	12	16	2472	14	10	9	4	4	1	5
9.30	2585	11	3	6	9	4	15	15	2478	11	14	6	2	5	1	5
9.15	2585	8	6	4	7	6	13	19	2483	17	6	2	3	5	3	3
9.00	2585	8	3	6	4	7	15	5	2503	11	5	6	2	3	3	4
8.85	2585	6	2	10	2	8	8	10	2509	5	7	6	0	4	3	5
8.70	2585	6	2	7	1	9	13	10	2509	3	5	6	1	5	4	4
8.55	2585	6	3	6	1	4	10	15	2516	3	1	4	4	7	1	4
8.40	2585	5	5	2	2	4	6	9	2530	4	1	2	3	7	0	5
8.25	2585	4	3	3	4	3	6	11	2529	5	3	1	5	3	1	4
8.10	2585	3	4	1	1	6	5	13	2526	7	4	4	3	4	0	4
7.95	2585	3	3	3	1	2	10	15	2519	10	6	3	4	1	1	4
7.80	2585	4	3	2	1	9	6	6	2527	7	10	2	1	2	2	3
7.65	2565	0	6	4	2	8	5	6	2534	7	0	5	2	1	3	2
7.50	2585	0	6	3	2	7	7	9	2530	7	2	4	2	2	3	1
7.35	2585	0	4	4	3	5	8	4	2536	6	5	3	0	5	1	1
7.20	2585	0	1	4	4	3	8	7	2538	5	6	2	2	2	2	1
7.05	2585	0	1	4	3	4	4	7	2544	7	2	1	0	4	4	0
6.90	2585	0	1	2	4	4	5	2	2551	6	1	1	1	4	3	0
6.75	2585	0	1	3	2	4	1	6	2550	3	6	3	2	2	2	0
6.60	2585	0	1	3	3	2	2	2	2555	4	4	2	3	3	1	0
6.45	2585	0	0	2	3	4	3	2	2556	4	2	2	3	3	1	0
6.30	2585	0	0	2	2	2	4	5	2555	6	1	0	3	4	1	0
6.15	2585	0	1	0	3	2	2	2	2558	5	5	3	2	0	2	0
6.00	2585	0	1	1	1	1	1	6	2555	6	5	5	1	1	1	0
5.85	2585	0	1	1	0	2	1	3	2561	4	6	2	2	2	0	0
5.70	2585	0	0	2	1	1	2	1	2564	3	8	1	0	2	0	0
5.55	2585	0	0	1	2	1	4	3	2560	8	4	1	0	1	0	0
5.40	2585	0	1	1	0	1	4	2	2565	6	3	2	0	0	0	0
5.25	2585	0	1	1	0	1	2	4	2566	6	1	3	0	0	0	0
5.10	2585	0	1	2	0	1	1	5	2563	4	7	1	0	0	0	0
4.95	2585	0	1	1	2	0	3	2	2563	8	2	2	1	0	0	0
4.80	2585	0	0	2	2	3	1	3	2565	3	2	1	2	1	0	0
4.65	2584	0	0	2	2	3	2	4	2564	2	2	1	0	1	1	0
4.50	2583	0	0	2	2	3	2	3	2565	1	2	1	1	0	0	1
4.35	2582	0	0	2	1	1	5	2	2565	3	1	0	1	0	0	1
4.20	2581	0	0	1	2	2	4	4	2560	2	5	0	0	1	0	0
4.05	2579	0	0	2	3	4	0	2	2562	2	1	2	0	1	0	0
3.90	2575	0	0	1	3	3	3	0	2561	1	1	1	0	0	1	0
3.75	2573	0	0	1	3	1	1	2	2562	0	1	0	1	0	1	0
3.60	2572	0	0	2	1	1	1	0	2564	1	0	0	1	1	0	0
3.45	2571	0	0	1	1	1	0	4	2561	1	0	1	1	0	0	0
3.30	2570	0	0	0	3	2	0	0	2562	1	1	1	0	0	0	0
3.15	2570	0	1	1	0	0	3	0	2563	1	0	1	0	0	0	0
3.00	2570	1	0	1	0	0	0	3	2562	2	0	1	0	0	0	0
2.85	2568	1	0	1	0	0	1	0	2562	2	0	1	0	0	0	0
2.70	2567	0	1	0	0	1	1	0	2561	2	0	1	0	0	0	0
2.55	2565	0	0	1	0	0	0	2	2560	1	1	0	0	0	0	0
2.40	2548	0	0	0	0	0	2	0	2544	1	1	0	0	0	0	0
2.25	2502	0	0	0	0	0	1	0	2500	0	1	0	0	0	0	0
2.10	2388	0	0	0	0	0	0	1	2386	0	1	0	0	0	0	0
1.95	2306	0	0	0	0	0	0	1	2304	0	1	0	0	0	0	0
1.80	2281	0	0	0	0	0	0	1	2280	0	0	0	0	0	0	0
1.65	2225	0	0	0	0	0	0	1	2224	0	0	0	0	0	0	0
1.50	2116	0	0	0	0	0	0	1	2115	0	0	0	0	0	0	0
1.35	1863	0	0	0	0	0	0	1	1862	0	0	0	0	0	0	0
1.20	1609	0	0	0	0	0	0	0	1609	0	0	0	0	0	0	0
1.05	1572	0	0	0	0	0	0	0	1572	0	0	0	0	0	0	0
0.90	1551	0	0	0	0	0	0	0	1551	0	0	0	0	0	0	0
0.75	1530	0	0	0	0	0	0	0	1530	0	0	0	0	0	0	0
0.60	1501	0	0	0	0	0	0	0	1501	0	0	0	0	0	0	0
0.45	1419	0	0	0	0	0	0	0	1419	0	0	0	0	0	0	0

TABLE 7

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

NOTE: A containment envelope can be thought of as two Normal Operating Zones of equal width, one on each side of the extended runway centerline. Any aircraft that strays outside of the containment envelope may or may not be in the No Transgression Zone for simultaneous approaches to dual parallel runways such as those collected for this study.

VIEW 1

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
10.50	2827	92	94	95	96	97	3
10.35	2846	93	94	95	96	97	3
10.20	2860	93	95	95	96	97	3
10.05	2874	93	94	95	96	97	3
9.90	2890	93	95	95	96	97	3
9.75	2907	93	95	96	97	97	3
9.60	2920	94	95	96	97	98	2
9.45	2936	94	95	96	97	98	2
9.30	2954	94	95	96	97	98	2
9.15	2968	94	96	97	97	98	2
9.00	2979	95	96	97	98	98	2
8.85	2990	95	96	97	97	98	2
8.70	3003	95	96	97	98	98	2
8.55	3013	96	97	97	98	98	2
8.40	3021	96	97	97	98	98	2
8.25	3039	96	97	98	98	98	2
8.10	3053	96	97	98	98	98	2
7.95	3061	96	97	98	98	99	1
7.80	3072	97	97	98	98	99	1
7.65	3083	97	97	98	98	99	1
7.50	3089	97	97	98	98	99	1
7.35	3096	97	98	98	98	99	1
7.20	3102	97	98	98	99	99	1
7.05	3110	97	98	98	99	99	1
6.90	3124	98	98	98	99	99	1
6.75	3134	98	98	99	99	99	1
6.60	3140	98	98	99	99	99	1
6.45	3146	98	98	99	99	99	1
6.30	3154	98	99	99	99	99	1
6.15	3158	98	99	99	99	100	0
6.00	3164	98	99	99	99	100	0
5.85	3167	99	99	99	99	100	0
5.70	3171	99	99	99	99	100	0
5.55	3176	99	99	99	100	100	0

TABLE 7 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

VIEW 1

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	3183	99	99	99	100	100	0
5.25	3184	99	99	99	100	100	0
5.10	3188	99	99	99	100	100	0
4.95	3188	99	99	99	99	100	0
4.80	3189	99	99	99	99	100	0
4.65	3189	99	99	99	99	100	0
4.50	3189	99	99	99	99	100	0
4.35	3190	99	99	99	100	100	0
4.20	3188	99	99	99	100	100	0
4.05	3186	99	99	99	100	100	0
3.90	3182	99	99	99	100	100	0
3.75	3180	99	100	100	100	100	0
3.60	3181	99	100	100	100	100	0
3.45	3181	99	100	100	100	100	0
3.30	3181	99	100	100	100	100	0
3.15	3181	99	100	100	100	100	0
3.00	3181	100	100	100	100	100	0
2.85	3179	100	100	100	100	100	0
2.70	3178	100	100	100	100	100	0
2.55	3175	100	100	100	100	100	0
2.40	3152	100	100	100	100	100	0
2.25	3100	100	100	100	100	100	0
2.10	2972	100	100	100	100	100	0
1.95	2869	100	100	100	100	100	0
1.80	2841	100	100	100	100	100	0
1.65	2770	100	100	100	100	100	0
1.50	2631	100	100	100	100	100	0
1.35	2327	100	100	100	100	100	0
1.20	2003	100	100	100	100	100	0
1.05	1939	100	100	100	100	100	0
0.90	1916	100	100	100	100	100	0
0.75	1895	100	100	100	100	100	0
0.60	1864	100	100	100	100	100	0
0.45	1776	100	100	100	100	100	0

TABLE 8

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

NOTE: A containment envelope can be thought of as two Normal Operating Zones of equal width, one on each side of the extended runway centerline. Any aircraft that strays outside of the containment envelope may or may not be in the No Transgression Zone for simultaneous approaches to dual parallel runways such as those collected for this study.

VIEW 2

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

RANGE	NO. OF	PERCENT OF AIRCRAFT					
(NMI)	OBSERVATIONS	<500	<550	<600	<650	<700	>700
10.50	2605	94	96	97	98	98	2
10.35	2649	95	97	97	98	98	2
10.20	2680	95	97	97	98	98	2
10.05	2708	95	96	97	98	99	1
9.90	2739	95	97	97	98	98	2
9.75	2780	95	96	97	98	99	1
9.60	2816	95	96	97	98	99	1
9.45	2840	95	96	97	98	99	1
9.30	2857	95	96	98	98	99	1
9.15	2876	95	97	98	98	99	1
9.00	2899	96	97	98	98	99	1
8.85	2913	96	97	98	98	99	1
8.70	2935	96	97	98	98	99	1
8.55	2950	96	97	98	98	99	1
8.40	2965	97	98	98	99	99	1
8.25	2988	97	98	98	99	99	1
8.10	3001	97	98	98	99	99	1
7.95	3013	97	98	99	99	99	1
7.80	3020	97	98	98	99	99	1
7.65	3036	97	98	98	99	99	1
7.50	3048	97	98	98	99	99	1
7.35	3060	98	98	99	99	99	1
7.20	3068	98	98	99	99	99	1
7.05	3078	98	98	99	99	99	1
6.90	3098	98	98	99	99	99	1
6.75	3109	98	98	99	99	99	1
6.60	3119	98	99	99	99	100	0
6.45	3127	98	99	99	99	100	0
6.30	3134	98	99	99	99	100	0
6.15	3143	98	99	99	100	100	0
6.00	3155	98	99	99	99	100	0
5.85	3160	99	99	99	100	100	0
5.70	3163	99	99	100	100	100	0
5.55	3172	99	99	99	100	100	0

TABLE 8 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

VIEW 2

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	3177	99	99	100	100	100	0
5.25	3179	99	99	100	100	100	0
5.10	3182	99	99	99	100	100	0
4.95	3183	99	99	99	99	100	0
4.80	3184	99	99	99	99	100	0
4.65	3186	99	99	99	99	100	0
4.50	3187	99	99	99	99	100	0
4.35	3188	99	99	99	100	100	0
4.20	3186	99	99	99	100	100	0
4.05	3184	99	99	99	100	100	0
3.90	3180	99	99	100	100	100	0
3.75	3180	99	100	100	100	100	0
3.60	3180	100	100	100	100	100	0
3.45	3180	99	100	100	100	100	0
3.30	3180	99	100	100	100	100	0
3.15	3180	100	100	100	100	100	0
3.00	3180	100	100	100	100	100	0
2.85	3178	100	100	100	100	100	0
2.70	3177	100	100	100	100	100	0
2.55	3174	100	100	100	100	100	0
2.40	3151	100	100	100	100	100	0
2.25	3099	100	100	100	100	100	0
2.10	2971	100	100	100	100	100	0
1.95	2868	100	100	100	100	100	0
1.80	2840	100	100	100	100	100	0
1.65	2770	100	100	100	100	100	0
1.50	2631	100	100	100	100	100	0
1.35	2327	100	100	100	100	100	0
1.20	2003	100	100	100	100	100	0
1.05	1939	100	100	100	100	100	0
0.90	1916	100	100	100	100	100	0
0.75	1895	100	100	100	100	100	0
0.60	1864	100	100	100	100	100	0
0.45	1776	100	100	100	100	100	0

TABLE 9

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

NOTE: A containment envelope can be thought of as two Normal Operating Zones of equal width, one on each side of the extended runway centerline. Any aircraft that strays outside of the containment envelope may or may not be in the No Transgression Zone for simultaneous approaches to dual parallel runways such as those collected for this study.

VIEW 3

TIME PERIOD: 1/24/89 TO 3/20/89 2585 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
10.50	2585	94	96	97	98	98	2
10.35	2585	95	97	97	98	98	2
10.20	2585	95	97	97	98	98	2
10.05	2585	95	96	97	98	99	1
9.90	2585	95	97	97	98	98	2
9.75	2585	95	96	97	98	99	1
9.60	2585	96	97	98	98	99	1
9.45	2585	96	97	98	98	99	1
9.30	2585	96	97	98	98	99	1
9.15	2585	96	97	98	98	99	1
9.00	2585	97	97	98	99	99	1
8.85	2585	97	98	98	99	99	1
8.70	2585	97	98	98	99	99	1
8.55	2585	97	98	98	99	99	1
8.40	2585	98	98	99	99	99	1
8.25	2585	98	98	99	99	99	1
8.10	2585	98	98	99	99	99	1
7.95	2585	97	98	99	99	99	1
7.80	2585	98	98	99	99	99	1
7.65	2585	98	99	99	99	99	1
7.50	2585	98	98	99	99	99	1
7.35	2585	98	98	99	99	99	1
7.20	2585	98	99	99	99	100	0
7.05	2585	98	99	99	99	99	1
6.90	2585	99	99	99	99	100	0
6.75	2585	99	99	99	100	100	0
6.60	2585	99	99	99	99	100	0
6.45	2585	99	99	99	100	100	0
6.30	2585	99	99	99	100	100	0
6.15	2585	99	99	99	100	100	0
6.00	2585	99	99	100	100	100	0
5.85	2585	99	99	100	100	100	0
5.70	2585	99	99	100	100	100	0
5.55	2585	99	99	100	100	100	0

TABLE 9 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

VIEW 3

TIME PERIOD: 1/24/89 TO 3/20/89 2585 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	2585	99	100	100	100	100	0
5.25	2585	99	100	100	100	100	0
5.10	2585	99	99	100	100	100	0
4.95	2585	99	100	100	100	100	0
4.80	2585	99	99	100	100	100	0
4.65	2584	99	99	100	100	100	0
4.50	2583	99	99	100	100	100	0
4.35	2582	99	100	100	100	100	0
4.20	2581	99	99	100	100	100	0
4.05	2579	99	99	100	100	100	0
3.90	2575	99	99	100	100	100	0
3.75	2573	100	100	100	100	100	0
3.60	2572	100	100	100	100	100	0
3.45	2571	100	100	100	100	100	0
3.30	2570	100	100	100	100	100	0
3.15	2570	100	100	100	100	100	0
3.00	2570	100	100	100	100	100	0
2.85	2568	100	100	100	100	100	0
2.70	2567	100	100	100	100	100	0
2.55	2565	100	100	100	100	100	0
2.40	2548	100	100	100	100	100	0
2.25	2502	100	100	100	100	100	0
2.10	2388	100	100	100	100	100	0
1.95	2306	100	100	100	100	100	0
1.80	2281	100	100	100	100	100	0
1.65	2225	100	100	100	100	100	0
1.50	2116	100	100	100	100	100	0
1.35	1863	100	100	100	100	100	0
1.20	1609	100	100	100	100	100	0
1.05	1572	100	100	100	100	100	0
0.90	1551	100	100	100	100	100	0
0.75	1530	100	100	100	100	100	0
0.60	1501	100	100	100	100	100	0
0.45	1419	100	100	100	100	100	0

TABLE 10

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

NOTE: A containment envelope can be thought of as two Normal Operating Zones of equal width, one on each side of the extended runway centerline. Any aircraft that strays outside of the containment envelope may or may not be in the No Transgression Zone for simultaneous approaches to dual parallel runways such as those collected for this study.

VIEW 1

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT <500	<550	<600	<650	<700	>700
10.50	2827	2592	2657	2689	2715	2732	95
10.35	2846	2638	2686	2710	2739	2751	95
10.20	2860	2655	2703	2724	2754	2768	92
10.05	2874	2670	2707	2737	2768	2787	87
9.90	2890	2688	2733	2757	2784	2805	85
9.75	2907	2713	2752	2785	2814	2833	74
9.60	2920	2737	2773	2808	2834	2850	70
9.45	2936	2753	2789	2823	2846	2865	71
9.30	2954	2780	2810	2847	2870	2886	68
9.15	2968	2801	2847	2870	2891	2904	64
9.00	2979	2828	2855	2887	2907	2919	60
8.85	2990	2850	2876	2898	2914	2923	67
8.70	3003	2860	2882	2910	2928	2937	66
8.55	3013	2882	2910	2925	2940	2951	62
8.40	3021	2905	2931	2943	2956	2967	54
8.25	3039	2927	2952	2968	2977	2990	49
8.10	3053	2938	2964	2982	2999	3007	46
7.95	3061	2940	2976	2994	3009	3018	43
7.80	3072	2968	2986	3005	3025	3030	42
7.65	3083	2984	3005	3018	3036	3046	37
7.50	3089	2988	3010	3025	3040	3049	40
7.35	3096	3005	3019	3037	3045	3053	43
7.20	3102	3014	3030	3050	3057	3065	37
7.05	3110	3028	3048	3058	3067	3074	36
6.90	3124	3053	3066	3075	3082	3092	32
6.75	3134	3061	3076	3087	3098	3106	28
6.60	3140	3075	3087	3099	3104	3116	24
6.45	3146	3088	3097	3105	3117	3127	19
6.30	3154	3093	3108	3120	3129	3138	16
6.15	3158	3102	3116	3131	3139	3146	12
6.00	3164	3108	3127	3137	3145	3151	13
5.85	3167	3121	3134	3143	3150	3154	13
5.70	3171	3128	3138	3154	3155	3158	13
5.55	3176	3129	3148	3159	3162	3167	9

TABLE 10 (continued)

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

VIEW 1

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	3183	3142	3156	3166	3172	3173	10
5.25	3184	3143	3158	3165	3170	3173	11
5.10	3188	3147	3156	3166	3174	3176	12
4.95	3188	3144	3155	3163	3167	3176	12
4.80	3189	3145	3155	3162	3166	3176	13
4.65	3189	3144	3157	3162	3166	3175	14
4.50	3189	3147	3156	3162	3172	3177	12
4.35	3190	3153	3160	3170	3175	3179	11
4.20	3188	3149	3159	3170	3175	3178	10
4.05	3186	3151	3160	3167	3173	3177	9
3.90	3182	3154	3160	3166	3172	3176	6
3.75	3180	3158	3165	3168	3169	3175	5
3.60	3181	3165	3168	3170	3171	3174	7
3.45	3181	3162	3170	3170	3173	3176	5
3.30	3181	3164	3166	3168	3173	3177	4
3.15	3181	3165	3169	3173	3175	3175	6
3.00	3181	3168	3173	3173	3175	3175	6
2.85	3179	3168	3171	3171	3173	3174	5
2.70	3178	3166	3169	3170	3173	3176	2
2.55	3175	3165	3168	3172	3173	3173	2
2.40	3152	3145	3147	3151	3151	3151	1
2.25	3100	3097	3097	3099	3099	3099	1
2.10	2972	2969	2970	2971	2971	2971	1
1.95	2869	2865	2866	2868	2868	2868	1
1.80	2841	2837	2838	2840	2840	2840	1
1.65	2770	2767	2769	2770	2770	2770	0
1.50	2631	2630	2631	2631	2631	2631	0
1.35	2327	2326	2327	2327	2327	2327	0
1.20	2003	2003	2003	2003	2003	2003	0
1.05	1939	1939	1939	1939	1939	1939	0
0.90	1916	1916	1916	1916	1916	1916	0
0.75	1895	1895	1895	1895	1895	1895	0
0.60	1864	1863	1864	1864	1864	1864	0
0.45	1776	1775	1775	1776	1776	1776	0

TABLE 11

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

NOTE: A containment envelope can be thought of as two Normal Operating Zones of equal width, one on each side of the extended runway centerline. Any aircraft that strays outside of the containment envelope may or may not be in the No Transgression Zone for simultaneous approaches to dual parallel runways such as those collected for this study.

VIEW 2

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

RANGE	NO. OF	NUMBER OF AIRCRAFT					
(NMI)	OBSERVATIONS	<500	<550	<600	<650	<700	>700
10.50	2605	2461	2509	2532	2553	2565	40
10.35	2649	2518	2559	2575	2598	2605	44
10.20	2680	2548	2589	2606	2628	2639	41
10.05	2708	2573	2602	2629	2654	2670	38
9.90	2739	2605	2644	2662	2682	2697	42
9.75	2780	2646	2680	2706	2728	2745	35
9.60	2816	2674	2705	2738	2763	2779	37
9.45	2840	2694	2729	2761	2783	2800	40
9.30	2857	2718	2748	2786	2803	2817	40
9.15	2876	2746	2789	2812	2826	2841	35
9.00	2899	2785	2808	2836	2855	2864	35
8.85	2913	2808	2829	2850	2867	2872	41
8.70	2935	2824	2844	2870	2889	2894	41
8.55	2950	2846	2871	2887	2902	2910	40
8.40	2965	2872	2896	2911	2922	2930	35
8.25	2988	2898	2923	2938	2947	2960	28
8.10	3001	2910	2935	2954	2970	2977	24
7.95	3013	2912	2949	2968	2983	2989	24
7.80	3020	2938	2956	2974	2992	2995	25
7.65	3036	2960	2980	2990	3007	3013	23
7.50	3048	2966	2987	3000	3014	3021	27
7.35	3060	2985	2999	3017	3025	3030	30
7.20	3068	2995	3011	3031	3038	3044	24
7.05	3078	3009	3029	3038	3047	3054	24
6.90	3098	3038	3051	3060	3067	3077	21
6.75	3109	3044	3059	3069	3080	3089	20
6.60	3119	3062	3073	3086	3092	3104	15
6.45	3127	3077	3086	3094	3106	3115	12
6.30	3134	3082	3097	3108	3116	3123	11
6.15	3143	3093	3106	3121	3129	3135	8
6.00	3155	3101	3121	3131	3138	3144	11
5.85	3160	3118	3132	3141	3146	3150	10
5.70	3163	3125	3135	3150	3151	3153	10
5.55	3172	3126	3145	3156	3159	3165	7

TABLE 11 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

VIEW 2

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	3177	3140	3154	3163	3169	3170	7
5.25	3179	3143	3158	3164	3169	3171	8
5.10	3182	3145	3154	3164	3172	3174	8
4.95	3183	3142	3153	3161	3165	3174	9
4.80	3184	3143	3152	3159	3163	3173	11
4.65	3186	3143	3156	3161	3165	3174	12
4.50	3187	3146	3155	3161	3171	3176	11
4.35	3188	3152	3159	3169	3174	3178	10
4.20	3186	3148	3158	3169	3174	3177	9
4.05	3184	3150	3159	3166	3172	3176	8
3.90	3180	3153	3159	3165	3171	3175	5
3.75	3180	3158	3166	3169	3170	3176	4
3.60	3180	3165	3168	3170	3171	3174	6
3.45	3180	3162	3170	3170	3173	3176	4
3.30	3180	3164	3166	3168	3173	3177	3
3.15	3180	3165	3169	3173	3175	3175	5
3.00	3180	3168	3173	3173	3175	3175	5
2.85	3178	3168	3171	3171	3173	3174	4
2.70	3177	3166	3169	3170	3173	3176	1
2.55	3174	3165	3168	3172	3173	3173	1
2.40	3151	3145	3147	3151	3151	3151	0
2.25	3099	3097	3097	3099	3099	3099	0
2.10	2971	2969	2970	2971	2971	2971	0
1.95	2868	2865	2866	2868	2868	2868	0
1.80	2840	2837	2838	2840	2840	2840	0
1.65	2770	2767	2769	2770	2770	2770	0
1.50	2631	2630	2631	2631	2631	2631	0
1.35	2327	2326	2327	2327	2327	2327	0
1.20	2003	2003	2003	2003	2003	2003	0
1.05	1939	1939	1939	1939	1939	1939	0
0.90	1916	1916	1916	1916	1916	1916	0
0.75	1895	1895	1895	1895	1895	1895	0
0.60	1864	1863	1864	1864	1864	1864	0
0.45	1776	1775	1775	1776	1776	1776	0

TABLE 12

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

NOTE: A containment envelope can be thought of as two Normal Operating Zones of equal width, one on each side of the extended runway centerline. Any aircraft that strays outside of the containment envelope may or may not be in the No Transgression Zone for simultaneous approaches to dual parallel runways such as those collected for this study.

VIEW 3

TIME PERIOD: 1/24/89 TO 3/20/89 2585 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT <500	<550	<600	<650	<700	>700
10.50	2585	2441	2489	2512	2533	2545	40
10.35	2585	2456	2497	2513	2536	2543	42
10.20	2585	2458	2497	2513	2535	2546	39
10.05	2585	2456	2485	2511	2535	2551	34
9.90	2585	2457	2495	2512	2532	2546	39
9.75	2585	2462	2494	2518	2539	2554	31
9.60	2585	2472	2497	2526	2545	2555	30
9.45	2585	2472	2503	2524	2539	2553	32
9.30	2585	2478	2504	2533	2543	2554	31
9.15	2585	2483	2520	2538	2546	2556	29
9.00	2585	2503	2519	2539	2552	2558	27
8.85	2585	2509	2524	2539	2553	2555	30
8.70	2585	2509	2523	2540	2555	2557	28
8.55	2585	2517	2535	2545	2553	2558	27
8.40	2585	2530	2543	2550	2556	2561	24
8.25	2585	2529	2545	2555	2558	2567	18
8.10	2585	2526	2546	2555	2565	2569	16
7.95	2585	2520	2544	2560	2565	2570	15
7.80	2585	2527	2541	2556	2567	2569	16
7.65	2585	2535	2547	2552	2565	2569	16
7.50	2585	2530	2546	2555	2566	2571	14
7.35	2585	2536	2546	2559	2567	2570	15
7.20	2585	2538	2551	2564	2569	2575	10
7.05	2585	2544	2558	2564	2569	2572	13
6.90	2585	2552	2559	2565	2570	2575	10
6.75	2585	2550	2559	2566	2573	2577	8
6.60	2585	2555	2561	2567	2571	2577	8
6.45	2585	2557	2562	2567	2573	2579	6
6.30	2585	2555	2566	2571	2573	2578	7
6.15	2585	2558	2565	2572	2577	2582	3
6.00	2585	2555	2567	2573	2579	2581	4
5.85	2585	2561	2569	2575	2579	2581	4
5.70	2585	2564	2568	2579	2580	2581	4
5.55	2585	2560	2571	2580	2581	2583	2

TABLE 12 (continued)

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ENVELOPE

NOTE: A containment envelope can be thought of as two Normal Operating Zones of equal width, one on each side of the extended runway centerline. Any aircraft that strays outside of the containment envelope may or may not be in the No Transgression Zone for simultaneous approaches to dual parallel runways such as those collected for this study.

VIEW 3

TIME PERIOD: 1/24/89 TO 3/20/89 2585 AIRCRAFT

RANGE	NO. OF	NUMBER OF AIRCRAFT					
(NMI)	OBSERVATIONS	<500	<550	<600	<65C	<700	>700
5.40	2585	2565	2573	2580	2583	2583	2
5.25	2585	2567	2576	2579	2583	2583	2
5.10	2585	2564	2572	2580	2582	2582	3
4.95	2585	2564	2573	2578	2580	2583	2
4.80	2585	2565	2571	2574	2578	2582	3
4.65	2584	2564	2570	2574	2578	2580	4
4.50	2583	2565	2569	2573	2577	2580	3
4.35	2582	2565	2570	2577	2577	2579	3
4.20	2581	2560	2566	2576	2577	2579	2
4.05	2579	2562	2566	2567	2573	2576	3
3.90	2575	2561	2562	2566	2570	2573	2
3.75	2573	2562	2564	2566	2567	2571	2
3.60	2572	2564	2565	2566	2567	2569	3
3.45	2571	2561	2566	2566	2568	2570	1
3.30	2570	2562	2563	2564	2567	2570	0
3.15	2570	2563	2564	2567	2568	2568	2
3.00	2570	2562	2567	2567	2568	2568	2
2.85	2568	2562	2565	2565	2566	2567	1
2.70	2567	2561	2563	2564	2566	2566	1
2.55	2565	2560	2563	2564	2564	2564	1
2.40	2548	2544	2545	2548	2548	2548	0
2.25	2502	2500	2500	2502	2502	2502	0
2.10	2388	2386	2387	2388	2388	2388	0
1.95	2306	2304	2305	2306	2306	2306	0
1.80	2281	2280	2281	2281	2281	2281	0
1.65	2225	2224	2225	2225	2225	2225	0
1.50	2116	2115	2116	2116	2116	2116	0
1.35	1863	1862	1863	1863	1863	1863	0
1.20	1609	1609	1609	1609	1609	1609	0
1.05	1572	1572	1572	1572	1572	1572	0
0.90	1551	1551	1551	1551	1551	1551	0
0.75	1530	1530	1530	1530	1530	1530	0
0.60	1501	1501	1501	1501	1501	1501	0
0.45	1419	1419	1419	1419	1419	1419	0

TABLE 13

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

NOTE: A Containment Zone includes the Normal Operating Zone (NOZ) of the specified width and is unbounded on the side of the extended runway centerline away from the adjacent parallel approach. Thus any aircraft that oversteps the containment zone while approaching a dual parallel runway will, by definition, be in the No Transgression Zone.

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

VIEW 1

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
10.50	2827	96	97	97	98	98	2
10.35	2846	96	97	98	98	98	2
10.20	2860	96	97	97	98	98	2
10.05	2874	96	97	98	98	98	2
9.90	2890	96	97	97	98	98	2
9.75	2907	96	97	98	98	99	1
9.60	2920	97	97	98	99	99	1
9.45	2936	97	97	98	99	99	1
9.30	2954	97	98	98	99	99	1
9.15	2968	97	98	98	99	99	1
9.00	2979	97	98	98	99	99	1
8.85	2990	98	98	98	99	99	1
8.70	3003	98	98	98	98	99	1
8.55	3013	98	98	98	99	99	1
8.40	3021	98	98	99	99	99	1
8.25	3039	98	99	99	99	99	1
8.10	3053	98	98	99	99	99	1
7.95	3061	98	98	99	99	99	1
7.80	3072	98	99	99	99	99	1
7.65	3083	98	99	99	99	99	1
7.50	3089	98	99	99	99	99	1
7.35	3096	98	99	99	99	99	1
7.20	3102	98	99	99	99	99	1
7.05	3110	99	99	99	99	99	1
6.90	3124	99	99	99	99	99	1
6.75	3134	99	99	99	99	99	1
6.60	3140	99	99	99	99	99	1
6.45	3146	99	99	99	99	99	1
6.30	3154	99	99	99	99	100	0
6.15	3158	99	99	99	100	100	0
6.00	3164	99	99	99	100	100	0
5.85	3167	99	99	100	100	100	0
5.70	3171	99	99	100	100	100	0
5.55	3176	99	100	100	100	100	0

TABLE 13 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

VIEW 1

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	3183	99	100	100	100	100	0
5.25	3184	99	100	100	100	100	0
5.10	3188	99	99	100	100	100	0
4.95	3188	99	99	100	100	100	0
4.80	3189	99	99	100	100	100	0
4.65	3189	99	99	100	100	100	0
4.50	3189	99	99	100	100	100	0
4.35	3190	99	100	100	100	100	0
4.20	3188	99	99	100	100	100	0
4.05	3186	99	100	100	100	100	0
3.90	3182	100	100	100	100	100	0
3.75	3180	100	100	100	100	100	0
3.60	3181	100	100	100	100	100	0
3.45	3181	100	100	100	100	100	0
3.30	3181	100	100	100	100	100	0
3.15	3181	100	100	100	100	100	0
3.00	3181	100	100	100	100	100	0
2.85	3179	100	100	100	100	100	0
2.70	3178	100	100	100	100	100	0
2.55	3175	100	100	100	100	100	0
2.40	3152	100	100	100	100	100	0
2.25	3100	100	100	100	100	100	0
2.10	2972	100	100	100	100	100	0
1.95	2869	100	100	100	100	100	0
1.80	2841	100	100	100	100	100	0
1.65	2770	100	100	100	100	100	0
1.50	2631	100	100	100	100	100	0
1.35	2327	100	100	100	100	100	0
1.20	2003	100	100	100	100	100	0
1.05	1939	100	100	100	100	100	0
0.90	1916	100	100	100	100	100	0
0.75	1895	100	100	100	100	100	0
0.60	1864	100	100	100	100	100	0
0.45	1776	100	100	100	100	100	0

TABLE 14

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

NOTE: A Containment Zone includes the Normal Operating Zone (NOZ) of the specified width and is unbounded on the side of the extended runway centerline away from the adjacent parallel approach. Thus any aircraft that oversteps the containment zone while approaching a dual parallel runway will, by definition, be in the No Transgression Zone.

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

VIEW 2

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
10.50	2605	98	99	99	99	99	1
10.35	2649	98	99	99	99	100	0
10.20	2680	98	99	99	99	100	0
10.05	2708	98	98	99	99	100	0
9.90	2739	98	99	99	99	99	1
9.75	2780	98	98	99	99	100	0
9.60	2816	98	98	99	99	100	0
9.45	2840	98	98	99	99	99	1
9.30	2857	98	98	99	99	99	1
9.15	2876	98	99	99	99	99	1
9.00	2899	98	99	99	99	100	0
8.85	2913	99	99	99	99	99	1
8.70	2935	99	99	99	99	99	1
8.55	2950	99	99	99	99	99	1
8.40	2965	99	99	99	99	99	1
8.25	2988	99	99	99	99	100	0
8.10	3001	99	99	99	100	100	0
7.95	3013	99	99	99	100	100	0
7.80	3020	99	99	99	100	100	0
7.65	3036	99	99	99	100	100	0
7.50	3048	99	99	99	99	100	0
7.35	3060	99	99	99	99	99	1
7.20	3068	99	99	99	99	100	0
7.05	3078	99	99	99	99	100	0
6.90	3098	99	99	99	99	100	0
6.75	3109	99	99	99	100	100	0
6.60	3119	99	99	99	100	100	0
6.45	3127	99	99	99	100	100	0
6.30	3134	99	99	99	100	100	0
6.15	3143	99	99	100	100	100	0
6.00	3155	99	99	100	100	100	0
5.85	3160	99	99	100	100	100	0
5.70	3163	99	99	100	100	100	0
5.55	3172	99	100	100	100	100	0

TABLE 14 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

VIEW 2

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	3177	99	100	100	100	100	0
5.25	3179	99	100	100	100	100	0
5.10	3182	99	99	100	100	100	0
4.95	3183	99	99	100	100	100	0
4.80	3184	99	99	100	100	100	0
4.65	3186	99	99	100	100	100	0
4.50	3187	99	99	100	100	100	0
4.35	3188	99	100	100	100	100	0
4.20	3186	99	100	100	100	100	0
4.05	3184	100	100	100	100	100	0
3.90	3180	100	100	100	100	100	0
3.75	3180	100	100	100	100	100	0
3.60	3180	100	100	100	100	100	0
3.45	3180	100	100	100	100	100	0
3.30	3180	100	100	100	100	100	0
3.15	3180	100	100	100	100	100	0
3.00	3180	100	100	100	100	100	0
2.85	3178	100	100	100	100	100	0
2.70	3177	100	100	100	100	100	0
2.55	3174	100	100	100	100	100	0
2.40	3151	100	100	100	100	100	0
2.25	3099	100	100	100	100	100	0
2.10	2971	100	100	100	100	100	0
1.95	2868	100	100	100	100	100	0
1.80	2840	100	100	100	100	100	0
1.65	2770	100	100	100	100	100	0
1.50	2631	100	100	100	100	100	0
1.35	2327	100	100	100	100	100	0
1.20	2003	100	100	100	100	100	0
1.05	1939	100	100	100	100	100	0
0.90	1916	100	100	100	100	100	0
0.75	1895	100	100	100	100	100	0
0.60	1864	100	100	100	100	100	0
0.45	1776	100	100	100	100	100	0

TABLE 15

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

NOTE: A Containment Zone includes the Normal Operating Zone (NOZ) of the specified width and is unbounded on the side of the extended runway centerline away from the adjacent parallel approach. Thus any aircraft that oversteps the containment zone while approaching a dual parallel runway will, by definition, be in the No Transgression Zone.

TIME PERIOD: 1/24/89 TO 3/20/89 2585 AIRCRAFT

VIEW 3

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
10.50	2585	98	99	99	99	99	1
10.35	2585	98	99	99	99	100	0
10.20	2585	98	99	99	99	100	0
10.05	2585	98	98	99	99	100	0
9.90	2585	98	99	99	99	99	1
9.75	2585	98	98	99	99	100	0
9.60	2585	98	99	99	99	100	0
9.45	2585	98	99	99	99	100	0
9.30	2585	98	99	99	99	100	0
9.15	2585	98	99	99	99	100	0
9.00	2585	99	99	99	100	100	0
8.85	2585	99	99	99	100	100	0
8.70	2585	99	99	99	99	99	1
8.55	2585	99	99	99	99	100	0
8.40	2585	99	99	99	99	100	0
8.25	2585	99	99	99	99	100	0
8.10	2585	99	99	99	100	100	0
7.95	2585	99	99	99	100	100	0
7.80	2585	99	99	100	100	100	0
7.65	2585	99	99	99	100	100	0
7.50	2585	99	99	100	100	100	0
7.35	2585	99	99	100	100	100	0
7.20	2585	99	99	100	100	100	0
7.05	2585	99	100	100	100	100	0
6.90	2585	99	100	100	100	100	0
6.75	2585	99	99	100	100	100	0
6.60	2585	99	99	100	100	100	0
6.45	2585	99	100	100	100	100	0
6.30	2585	99	100	100	100	100	0
6.15	2585	99	100	100	100	100	0
6.00	2585	99	99	100	100	100	0
5.85	2585	99	100	100	100	100	0
5.70	2585	99	100	100	100	100	0
5.55	2585	99	100	100	100	100	0

TABLE 15 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

TIME PERIOD: 1/24/89 TO 3/20/89 2585 AIRCRAFT

VIEW 3

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	2585	100	100	100	100	100	0
5.25	2585	100	100	100	100	100	0
5.10	2585	100	100	100	100	100	0
4.95	2585	99	100	100	100	100	0
4.80	2585	100	100	100	100	100	0
4.65	2584	100	100	100	100	100	0
4.50	2583	100	100	100	100	100	0
4.35	2582	100	100	100	100	100	0
4.20	2581	100	100	100	100	100	0
4.05	2579	100	100	100	100	100	0
3.90	2575	100	100	100	100	100	0
3.75	2573	100	100	100	100	100	0
3.60	2572	100	100	100	100	100	0
3.45	2571	100	100	100	100	100	0
3.30	2570	100	100	100	100	100	0
3.15	2570	100	100	100	100	100	0
3.00	2570	100	100	100	100	100	0
2.85	2568	100	100	100	100	100	0
2.70	2567	100	100	100	100	100	0
2.55	2565	100	100	100	100	100	0
2.40	2548	100	100	100	100	100	0
2.25	2502	100	100	100	100	100	0
2.10	2388	100	100	100	100	100	0
1.95	2306	100	100	100	100	100	0
1.80	2281	100	100	100	100	100	0
1.65	2225	100	100	100	100	100	0
1.50	2116	100	100	100	100	100	0
1.35	1863	100	100	100	100	100	0
1.20	1609	100	100	100	100	100	0
1.05	1572	100	100	100	100	100	0
0.90	1551	100	100	100	100	100	0
0.75	1530	100	100	100	100	100	0
0.60	1501	100	100	100	100	100	0
0.45	1419	100	100	100	100	100	0

TABLE 16

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

NOTE: A Containment Zone includes the Normal Operating Zone (NOZ) of the specified width and is unbounded on the side of the extended runway centerline away from the adjacent parallel approach. Thus any aircraft that oversteps the containment zone while approaching a dual parallel runway will, by definition, be in the No Transgression Zone.

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

VIEW 1

RANGE	NO. OF	NUMBER OF AIRCRAFT					
(NMI)	OBSERVATIONS	<500	<550	<600	<650	<700	>700
10.50	2827	2715	2742	2756	2770	2778	49
10.35	2846	2743	2764	2778	2789	2799	47
10.20	2860	2754	2776	2788	2804	2813	47
10.05	2874	2765	2787	2806	2820	2827	47
9.90	2890	2775	2803	2817	2837	2844	46
9.75	2907	2798	2819	2841	2860	2868	39
9.60	2920	2818	2843	2864	2877	2886	34
9.45	2936	2843	2859	2878	2894	2900	36
9.30	2954	2867	2881	2897	2912	2917	37
9.15	2968	2887	2908	2918	2928	2934	34
9.00	2979	2901	2918	2931	2942	2948	31
8.85	2990	2922	2933	2943	2949	2954	36
8.70	3003	2934	2942	2949	2956	2964	39
8.55	3013	2948	2959	2962	2971	2979	34
8.40	3021	2962	2974	2977	2983	2990	31
8.25	3039	2987	2995	3001	3004	3011	28
8.10	3053	2994	3005	3013	3020	3026	27
7.95	3061	3000	3015	3022	3030	3038	23
7.80	3072	3016	3026	3039	3046	3050	22
7.65	3083	3032	3044	3049	3057	3064	19
7.50	3089	3038	3049	3055	3061	3065	24
7.35	3096	3048	3057	3063	3066	3068	28
7.20	3102	3055	3062	3072	3074	3077	25
7.05	3110	3065	3075	3079	3083	3084	26
6.90	3124	3084	3092	3096	3097	3100	24
6.75	3134	3093	3098	3106	3110	3114	20
6.60	3140	3100	3107	3115	3117	3122	18
6.45	3146	3110	3117	3121	3125	3130	16
6.30	3154	3118	3126	3130	3134	3140	14
6.15	3158	3124	3133	3141	3144	3147	11
6.00	3164	3132	3140	3146	3151	3154	10
5.85	3167	3139	3144	3152	3156	3159	8
5.70	3171	3144	3150	3161	3162	3163	8
5.55	3176	3149	3161	3167	3169	3170	6

TABLE 16 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

VIEW 1

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	3183	3158	3169	3173	3176	3177	6
5.25	3184	3158	3169	3173	3176	3177	7
5.10	3188	3163	3168	3176	3181	3181	7
4.95	3188	3161	3170	3173	3177	3182	6
4.80	3189	3165	3170	3175	3176	3183	6
4.65	3189	3165	3172	3175	3176	3181	8
4.50	3189	3166	3171	3174	3178	3181	8
4.35	3190	3170	3175	3178	3179	3182	8
4.20	3188	3169	3172	3177	3179	3180	8
4.05	3186	3170	3173	3177	3179	3180	6
3.90	3182	3170	3173	3175	3176	3177	5
3.75	3180	3170	3173	3174	3174	3176	4
3.60	3181	3172	3174	3175	3175	3177	4
3.45	3181	3170	3174	3174	3176	3178	3
3.30	3181	3171	3173	3175	3177	3178	3
3.15	3181	3172	3175	3176	3178	3178	3
3.00	3181	3174	3176	3176	3178	3178	3
2.85	3179	3172	3174	3174	3176	3176	3
2.70	3178	3171	3173	3173	3175	3177	1
2.55	3175	3169	3170	3173	3174	3174	1
2.40	3152	3147	3149	3151	3151	3151	1
2.25	3100	3098	3098	3099	3099	3099	1
2.10	2972	2970	2970	2971	2971	2971	1
1.95	2869	2866	2866	2868	2868	2868	1
1.80	2841	2839	2839	2840	2840	2840	1
1.65	2770	2768	2769	2770	2770	2770	0
1.50	2631	2631	2631	2631	2631	2631	0
1.35	2327	2327	2327	2327	2327	2327	0
1.20	2003	2003	2003	2003	2003	2003	0
1.05	1939	1939	1939	1939	1939	1939	0
0.90	1916	1916	1916	1916	1916	1916	0
0.75	1895	1895	1895	1895	1895	1895	0
0.60	1864	1864	1864	1864	1864	1864	0
0.45	1776	1776	1776	1776	1776	1776	0

TABLE 17

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

NOTE: A Containment Zone includes the Normal Operating Zone (NOZ) of the specified width and is unbounded on the side of the extended runway centerline away from the adjacent parallel approach. Thus any aircraft that oversteps the containment zone while approaching a dual parallel runway will, by definition, be in the No Transgression Zone.

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

VIEW 2

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT <500	<550	<600	<650	<700	>700
10.50	2605	2555	2569	2579	2588	2591	14
10.35	2649	2601	2617	2624	2631	2636	13
10.20	2680	2625	2644	2653	2663	2670	10
10.05	2708	2651	2667	2682	2693	2699	9
9.90	2739	2677	2700	2709	2722	2725	14
9.75	2780	2717	2734	2749	2763	2770	10
9.60	2816	2753	2772	2791	2799	2805	11
9.45	2840	2779	2793	2807	2821	2825	15
9.30	2857	2799	2811	2827	2836	2840	17
9.15	2876	2824	2842	2851	2856	2861	15
9.00	2899	2851	2864	2872	2881	2885	14
8.85	2913	2872	2879	2887	2893	2895	18
8.70	2935	2893	2898	2904	2910	2914	21
8.55	2950	2911	2919	2920	2926	2932	18
8.40	2965	2929	2938	2940	2944	2948	17
8.25	2988	2956	2963	2967	2969	2976	12
8.10	3001	2964	2974	2981	2986	2991	10
7.95	3013	2972	2986	2993	3000	3005	8
7.80	3020	2983	2992	3004	3009	3011	9
7.65	3036	3003	3014	3016	3024	3028	8
7.50	3048	3013	3023	3027	3032	3035	13
7.35	3060	3026	3034	3040	3043	3043	17
7.20	3068	3033	3040	3050	3052	3054	14
7.05	3078	3045	3055	3058	3062	3063	15
6.90	3098	3068	3076	3080	3081	3084	14
6.75	3109	3078	3083	3090	3094	3098	11
6.60	3119	3087	3094	3102	3105	3110	9
6.45	3127	3098	3105	3110	3114	3118	9
6.30	3134	3106	3114	3118	3121	3125	9
6.15	3143	3115	3123	3131	3134	3136	7
6.00	3155	3126	3134	3140	3145	3148	7
5.85	3160	3136	3141	3149	3152	3155	5
5.70	3163	3140	3146	3157	3158	3158	5
5.55	3172	3147	3159	3165	3167	3169	3

TABLE 17 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

TIME PERIOD: 1/24/89 TO 3/20/89 3197 AIRCRAFT

VIEW 2

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	3177	3155	3166	3170	3173	3174	3
5.25	3179	3156	3167	3171	3174	3175	4
5.10	3182	3160	3165	3173	3178	3178	4
4.95	3183	3158	3167	3170	3174	3179	4
4.80	3184	3162	3166	3171	3172	3179	5
4.65	3186	3163	3170	3173	3174	3179	7
4.50	3187	3165	3170	3173	3177	3180	7
4.35	3188	3169	3174	3177	3178	3181	7
4.20	3186	3168	3171	3176	3178	3179	7
4.05	3184	3169	3172	3176	3178	3179	5
3.90	3180	3169	3172	3174	3175	3176	4
3.75	3180	3171	3174	3175	3175	3177	3
3.60	3180	3172	3174	3175	3175	3177	3
3.45	3180	3170	3174	3174	3176	3178	2
3.30	3180	3171	3173	3175	3177	3178	2
3.15	3180	3172	3175	3176	3178	3178	2
3.00	3180	3174	3176	3176	3178	3178	2
2.85	3178	3172	3174	3174	3176	3176	2
2.70	3177	3171	3173	3173	3175	3177	0
2.55	3174	3169	3170	3173	3174	3174	0
2.40	3151	3147	3149	3151	3151	3151	0
2.25	3099	3098	3098	3099	3099	3099	0
2.10	2971	2970	2970	2971	2971	2971	0
1.95	2868	2866	2866	2868	2868	2868	0
1.80	2840	2839	2839	2840	2840	2840	0
1.65	2770	2768	2769	2770	2770	2770	0
1.50	2631	2631	2631	2631	2631	2631	0
1.35	2327	2327	2327	2327	2327	2327	0
1.20	2003	2003	2003	2003	2003	2003	0
1.05	1939	1939	1939	1939	1939	1939	0
0.90	1916	1916	1916	1916	1916	1916	0
0.75	1895	1895	1895	1895	1895	1895	0
0.60	1864	1864	1864	1864	1864	1864	0
0.45	1776	1776	1776	1776	1776	1776	0

TABLE 18

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

NOTE: A Containment Zone includes the Normal Operating Zone (NOZ) of the specified width and is unbounded on the side of the extended runway centerline away from the adjacent parallel approach. Thus any aircraft that oversteps the containment zone while approaching a dual parallel runway will, by definition, be in the No Transgression Zone.

TIME PERIOD: 1/24/89 TO 3/20/89 2585 AIRCRAFT

VIEW 3

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT <500	<550	<600	<650	<700	>700
10.50	2585	2535	2549	2559	2568	2571	14
10.35	2585	2538	2554	2561	2568	2573	12
10.20	2585	2533	2550	2559	2569	2576	9
10.05	2585	2530	2546	2561	2571	2577	8
9.90	2585	2524	2547	2556	2569	2572	13
9.75	2585	2526	2543	2557	2570	2576	9
9.60	2585	2533	2548	2565	2572	2577	8
9.45	2585	2538	2552	2562	2571	2575	10
9.30	2585	2541	2552	2566	2572	2574	11
9.15	2585	2546	2563	2569	2571	2574	11
9.00	2585	2551	2562	2567	2573	2575	10
8.85	2585	2555	2560	2567	2573	2573	12
8.70	2585	2557	2560	2565	2571	2572	13
8.55	2585	2561	2564	2565	2569	2573	12
8.40	2585	2563	2567	2568	2570	2573	12
8.25	2585	2563	2568	2571	2572	2577	8
8.10	2585	2559	2566	2570	2574	2577	8
7.95	2585	2556	2566	2572	2575	2579	6
7.80	2585	2558	2565	2575	2577	2578	7
7.65	2585	2565	2572	2572	2577	2579	6
7.50	2585	2564	2571	2573	2577	2579	6
7.35	2585	2564	2570	2575	2578	2578	7
7.20	2585	2565	2570	2576	2578	2580	5
7.05	2585	2567	2574	2576	2577	2577	8
6.90	2585	2569	2575	2576	2577	2578	7
6.75	2585	2567	2570	2576	2579	2581	4
6.60	2585	2568	2572	2576	2578	2581	4
6.45	2585	2570	2574	2576	2578	2581	4
6.30	2585	2570	2576	2577	2577	2580	5
6.15	2585	2568	2573	2578	2581	2583	2
6.00	2585	2566	2572	2577	2582	2583	2
5.85	2585	2569	2573	2579	2581	2583	2
5.70	2585	2571	2574	2582	2583	2583	2
5.55	2585	2571	2579	2583	2584	2584	1

TABLE 18 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

TIME PERIOD: 1/24/89 TO 3/20/89 2585 AIRCRAFT

VIEW 3

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	2585	2574	2580	2583	2585	2585	0
5.25	2585	2575	2581	2582	2585	2585	0
5.10	2585	2573	2577	2584	2585	2585	0
4.95	2585	2572	2580	2582	2584	2585	0
4.80	2585	2576	2579	2581	2582	2584	1
4.65	2584	2577	2579	2581	2582	2582	2
4.50	2583	2577	2578	2580	2581	2582	1
4.35	2582	2576	2579	2580	2580	2581	1
4.20	2581	2573	2575	2580	2580	2580	1
4.05	2579	2573	2575	2576	2578	2578	1
3.90	2575	2571	2572	2573	2574	2574	1
3.75	2573	2570	2570	2571	2571	2572	1
3.60	2572	2569	2570	2570	2570	2571	1
3.45	2571	2568	2569	2569	2570	2571	0
3.30	2570	2567	2568	2569	2570	2570	0
3.15	2570	2568	2569	2569	2570	2570	0
3.00	2570	2567	2569	2569	2570	2570	0
2.85	2568	2565	2567	2567	2568	2568	0
2.70	2567	2564	2566	2566	2567	2567	0
2.55	2565	2563	2564	2565	2565	2565	0
2.40	2548	2546	2547	2548	2548	2548	0
2.25	2502	2501	2501	2502	2502	2502	0
2.10	2388	2387	2387	2388	2388	2388	0
1.95	2306	2305	2305	2306	2306	2306	0
1.80	2281	2281	2281	2281	2281	2281	0
1.65	2225	2225	2225	2225	2225	2225	0
1.50	2116	2116	2116	2116	2116	2116	0
1.35	1863	1863	1863	1863	1863	1863	0
1.20	1609	1609	1609	1609	1609	1609	0
1.05	1572	1572	1572	1572	1572	1572	0
0.90	1551	1551	1551	1551	1551	1551	0
0.75	1530	1530	1530	1530	1530	1530	0
0.60	1501	1501	1501	1501	1501	1501	0
0.45	1419	1419	1419	1419	1419	1419	0

TABLE 19

MEASURED DEVIATION FROM EXTENDED RUNWAY CENTERLINE

AIR CARRIERS ONLY
VIEW 2

3197 AIRCRAFT

	AWAY FROM NTZ		TOWARD NTZ		TOTAL OBSERVATIONS		
RANGE	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	SAMPLE SIZE	MEAN	STANDARD DEVIATION
15.00	16	-187	16	128	32	-29	208
14.85	89	-158	70	155	159	-20	196
14.70	101	-156	64	174	165	-28	204
14.55	96	-179	74	180	170	-23	233
14.40	100	-183	75	193	175	-22	259
14.25	106	-198	83	197	189	-25	282
14.10	114	-220	84	230	198	-29	319
13.95	135	-242	94	238	229	-45	358
13.80	227	-218	163	214	390	-37	339
13.65	277	-213	216	200	493	-32	323
13.50	334	-199	260	206	594	-22	311
13.35	419	-190	323	196	742	-22	290
13.20	448	-191	351	193	799	-22	282
13.05	466	-188	354	204	820	-18	279
12.90	493	-189	370	208	863	-19	278
12.75	530	-197	399	225	929	-16	302
12.60	563	-196	424	221	987	-17	297
12.45	588	-190	454	214	1042	-14	287
12.30	607	-189	467	210	1074	-15	280
12.15	761	-182	576	201	1337	-17	268
12.00	805	-183	665	200	1470	-9	268
11.85	808	-189	740	187	1548	-9	266
11.70	878	-203	798	190	1676	-16	288
11.55	883	-204	823	182	1706	-18	280
11.40	906	-204	853	178	1759	-19	273
11.25	962	-202	879	172	1841	-24	266
11.10	1008	-203	882	167	1890	-30	262
10.95	1066	-199	862	170	1928	-34	260
10.80	1070	-202	884	166	1954	-36	255
10.65	1088	-198	914	163	2002	-33	248
10.50	1133	-191	935	165	2068	-30	247
10.35	1146	-189	954	166	2100	-28	246
10.20	1147	-186	979	165	2126	-25	243
10.05	1151	-182	996	160	2147	-23	238
9.90	1156	-177	1013	157	2169	-21	235
9.75	1172	-171	1031	157	2203	-18	233
9.60	1180	-172	1054	155	2234	-18	236
9.45	1183	-170	1072	153	2255	-16	234
9.30	1157	-173	1111	147	2268	-16	232
9.15	1146	-176	1138	141	2284	-18	228
9.00	1174	-172	1131	143	2305	-17	227
8.85	1149	-174	1166	140	2315	-16	225
8.70	1181	-170	1149	141	2330	-16	223
8.55	1202	-165	1137	141	2339	-16	217
8.40	1196	-166	1154	139	2350	-16	212
8.25	1205	-164	1164	141	2369	-14	208
8.10	1208	-162	1171	142	2379	-12	204
7.95	1203	-156	1185	142	2388	-8	201
7.80	1192	-150	1202	141	2394	-4	196
7.65	1179	-146	1228	140	2407	0	191

TABLE 19 (continued)

MEASURED DEVIATION FROM EXTENDED RUNWAY CENTERLINE

AIR CARRIERS ONLY
VIEW 2

3197 AIRCRAFT

RANGE	AWAY FROM NTZ SAMPLE SIZE	AWAY FROM NTZ MEAN	TOWARD NTZ SAMPLE SIZE	TOWARD NTZ MEAN	TOTAL OBSERVATIONS SAMPLE SIZE	TOTAL OBSERVATIONS MEAN	TOTAL OBSERVATIONS STANDARD DEVIATION
7.50	1170	-141	1248	138	2418	3	189
7.35	1177	-133	1250	137	2427	6	185
7.20	1155	-131	1278	133	2433	8	183
7.05	1153	-130	1286	131	2439	8	181
6.90	1164	-129	1287	129	2451	6	179
6.75	1174	-130	1286	127	2460	5	176
6.60	1193	-126	1276	126	2469	4	172
6.45	1232	-121	1242	125	2474	3	167
6.30	1241	-118	1237	121	2478	1	163
6.15	1271	-113	1214	117	2485	-1	159
6.00	1288	-110	1206	114	2494	-2	155
5.85	1290	-107	1208	108	2498	-3	150
5.70	1286	-107	1214	105	2500	-4	149
5.55	1300	-108	1206	104	2506	-6	151
5.40	1303	-110	1207	102	2510	-8	151
5.25	1322	-110	1189	103	2511	-9	151
5.10	1327	-111	1186	103	2513	-10	151
4.95	1331	-111	1183	105	2514	-9	151
4.80	1320	-111	1195	104	2515	-9	150
4.65	1333	-110	1185	106	2518	-9	149
4.50	1333	-109	1186	104	2519	-9	145
4.35	1337	-106	1183	100	2520	-10	140
4.20	1367	-100	1151	98	2518	-10	135
4.05	1360	-98	1157	93	2517	-10	129
3.90	1359	-95	1154	88	2513	-11	123
3.75	1381	-93	1132	85	2513	-13	119
3.60	1392	-90	1120	82	2512	-13	115
3.45	1401	-88	1112	80	2513	-14	112
3.30	1413	-85	1100	79	2513	-13	110
3.15	1407	-84	1106	77	2513	-13	108
3.00	1404	-82	1109	77	2513	-12	107
2.85	1383	-83	1128	75	2511	-12	105
2.70	1409	-81	1101	72	2510	-14	102
2.55	1471	-78	1036	70	2507	-17	97
2.40	1497	-77	991	66	2488	-20	93
2.25	1472	-75	970	64	2442	-20	90
2.10	1416	-73	921	63	2337	-19	88
1.95	1374	-74	881	61	2255	-21	87
1.80	1372	-73	865	59	2237	-22	86
1.65	1388	-73	793	58	2181	-25	84
1.50	1367	-73	707	55	2074	-30	82
1.35	1218	-71	609	52	1827	-30	76
1.20	1111	-68	470	46	1581	-34	70
1.05	1084	-66	448	38	1532	-35	63
0.90	1075	-63	440	36	1515	-34	61
0.75	1062	-61	436	35	1498	-33	59
0.60	1056	-60	421	33	1477	-33	59
0.45	976	-61	433	30	1409	-33	59
0.30	868	-59	429	29	1297	-30	60
0.15	794	-56	435	29	1229	-26	61

TABLE 20

MEASURED DEVIATION FROM EXTENDED RUNWAY CENTERLINE

AIR TAXIS ONLY
VIEW 2

3197 AIRCRAFT

RANGE	AWAY FROM NTZ SAMPLE SIZE	AWAY FROM NTZ MEAN	TOWARD NTZ SAMPLE SIZE	TOWARD NTZ MEAN	TOTAL OBSERVATIONS SAMPLE SIZE	TOTAL OBSERVATIONS MEAN	TOTAL OBSERVATIONS STANDARD DEVIATION
15.00	5	-204	0	0	5	-204	61
14.85	27	-211	8	247	35	-106	230
14.70	24	-225	12	216	36	-78	245
14.55	23	-234	13	224	36	-68	260
14.40	22	-276	15	210	37	-79	278
14.25	23	-305	16	236	39	-83	306
14.10	23	-314	17	242	40	-78	316
13.95	28	-292	22	416	50	19	597
13.80	42	-274	31	397	73	11	561
13.65	50	-258	39	341	89	5	531
13.50	59	-246	44	351	103	9	521
13.35	83	-263	64	293	147	-21	469
13.20	83	-270	70	277	153	-19	467
13.05	90	-261	67	312	157	-17	474
12.90	99	-244	71	328	170	-5	472
12.75	109	-254	83	329	192	-2	480
12.60	107	-258	97	318	204	16	476
12.45	115	-236	98	333	213	26	452
12.30	117	-218	105	306	222	30	417
12.15	145	-202	133	267	278	22	361
12.00	155	-197	142	260	297	22	339
11.85	166	-215	167	242	333	14	331
11.70	180	-225	175	237	355	3	322
11.55	187	-230	178	234	365	-4	313
11.40	194	-228	184	227	378	-7	304
11.25	211	-227	182	220	393	-20	296
11.10	226	-220	181	212	407	-27	285
10.95	235	-210	182	211	417	-26	276
10.80	232	-218	192	206	424	-26	272
10.65	237	-221	198	201	435	-29	268
10.50	247	-215	200	203	447	-28	266
10.35	250	-215	207	205	457	-24	268
10.20	250	-212	211	212	461	-18	270
10.05	249	-203	218	213	467	-9	269
9.90	254	-189	220	214	474	-2	266
9.75	251	-181	229	203	480	2	259
9.60	249	-173	235	197	484	7	251
9.45	248	-167	238	195	486	10	247
9.30	241	-165	249	190	490	15	244
9.15	234	-165	259	183	493	18	239
9.00	238	-159	256	186	494	20	239
8.85	234	-158	263	185	497	24	238
8.70	238	-161	264	186	502	21	238
8.55	242	-174	265	183	507	13	242
8.40	258	-172	252	192	510	8	245
8.25	258	-181	255	194	513	5	252
8.10	255	-183	260	191	515	6	255
7.95	258	-184	260	193	518	5	255
7.80	264	-175	255	200	519	9	251
7.65	262	-170	260	192	522	11	243

TABLE 20 (continued)

MEASURED DEVIATION FROM EXTENDED RUNWAY CENTERLINE

AIR CARRIERS ONLY
VIEW 2

3197 AIRCRAFT

RANGE	AWAY FROM NTZ SAMPLE SIZE	AWAY FROM NTZ MEAN	TOWARD NTZ SAMPLE SIZE	TOWARD NTZ MEAN	TOTAL OBSERVATIONS SAMPLE SIZE	TOTAL OBSERVATIONS MEAN	TOTAL OBSERVATIONS STANDARD DEVIATION
7.50	260	-166	263	186	523	11	237
7.35	256	-159	270	184	526	17	232
7.20	249	-156	279	180	528	22	229
7.05	252	-152	279	177	531	21	226
6.90	250	-152	288	174	538	23	221
6.75	253	-145	286	173	539	24	216
6.60	255	-146	285	174	540	23	215
6.45	261	-145	281	175	542	21	217
6.30	261	-150	284	172	545	18	219
6.15	266	-145	281	172	547	18	216
6.00	260	-145	288	166	548	18	212
5.85	259	-143	290	164	549	19	210
5.70	259	-142	291	164	550	20	209
5.55	248	-149	305	160	553	21	210
5.40	234	-154	320	155	554	24	207
5.25	237	-150	318	158	555	27	206
5.10	245	-146	311	163	556	27	205
4.95	242	-148	314	160	556	26	207
4.80	253	-144	303	165	556	25	209
4.65	258	-140	297	165	555	23	207
4.50	262	-142	293	164	555	20	206
4.35	265	-146	290	162	555	15	207
4.20	266	-149	289	154	555	9	209
4.05	271	-149	283	148	554	3	207
3.90	278	-144	276	145	554	0	201
3.75	278	-141	276	141	554	0	195
3.60	289	-131	266	143	555	1	188
3.45	293	-124	261	139	554	0	180
3.30	284	-121	270	126	554	-1	171
3.15	289	-115	265	124	554	-1	165
3.00	281	-113	273	116	554	0	159
2.85	278	-111	276	112	554	0	155
2.70	281	-106	273	110	554	0	149
2.55	278	-102	276	103	554	0	138
2.40	271	-98	280	95	551	0	130
2.25	281	-89	264	94	545	0	122
2.10	276	-81	250	91	526	1	116
1.95	269	-79	238	87	507	-1	111
1.80	272	-81	226	83	498	-6	108
1.65	279	-82	210	76	489	-14	105
1.50	276	-82	189	74	465	-19	101
1.35	264	-79	154	73	418	-23	96
1.20	243	-78	112	56	355	-36	83
1.05	230	-75	116	51	346	-32	78
0.90	227	-69	115	49	342	-29	76
0.75	229	-63	109	43	338	-29	68
0.60	224	-62	107	36	331	-31	63
0.45	208	-60	105	30	313	-29	61
0.30	171	-54	115	25	286	-22	56
0.15	161	-43	107	28	268	-15	50

TABLE 21

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

NOTE: A Containment Zone includes the Normal Operating Zone (NOZ) of the specified width and is unbounded on the side of the extended runway centerline away from the adjacent parallel approach. Thus any aircraft that oversteps the containment zone while approaching a dual parallel runway will, by definition, be in the No Transgression Zone.

AIR TAXIS ONLY VIEW 2

TIME PERIOD: 1/24/89 TO 3/20/89 558 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
10.50	447	97	98	99	99	100	0
10.35	457	97	98	98	99	100	0
10.20	461	97	98	98	99	100	0
10.05	467	96	97	98	99	99	1
9.90	474	96	97	97	99	99	1
9.75	480	95	96	97	99	99	1
9.60	484	96	97	98	99	99	1
9.45	486	96	97	98	99	99	1
9.30	490	97	97	98	99	99	1
9.15	493	97	98	98	99	99	1
9.00	494	96	98	98	99	99	1
8.85	497	97	98	98	99	99	1
8.70	502	97	97	98	98	98	2
8.55	507	97	97	98	98	99	1
8.40	510	98	98	98	98	99	1
8.25	513	98	98	98	99	99	1
8.10	515	97	98	98	99	99	1
7.95	518	97	98	98	99	99	1
7.80	519	97	98	99	99	99	1
7.65	522	98	98	98	98	99	1
7.50	523	97	98	98	98	99	1
7.35	526	97	98	98	99	99	1
7.20	528	97	98	98	99	99	1
7.05	531	97	98	98	99	99	1
6.90	538	98	99	99	99	99	1
6.75	539	98	98	99	99	99	1
6.60	540	97	98	99	99	99	1
6.45	542	98	98	98	99	99	1
6.30	545	97	98	99	99	99	1
6.15	547	98	98	99	99	99	1
6.00	548	97	98	99	99	99	1
5.85	549	98	98	99	99	99	1
5.70	550	97	98	99	99	99	1
5.55	553	98	99	99	100	100	0

TABLE 21 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

AIR TAXIS ONLY — VIEW 2

TIME PERIOD: 1/24/89 TO 3/20/89 — 558 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	PERCENT OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	554	98	99	99	100	100	0
5.25	555	98	99	99	100	100	0
5.10	556	97	98	99	100	100	0
4.95	556	97	99	99	99	100	0
4.80	556	98	98	99	99	100	0
4.65	555	97	98	99	99	99	1
4.50	555	98	98	99	99	99	1
4.35	555	98	99	99	99	99	1
4.20	555	98	98	99	99	99	1
4.05	554	98	99	99	99	99	1
3.90	554	99	99	99	99	100	0
3.75	554	99	99	99	99	100	0
3.60	555	99	99	99	99	100	0
3.45	554	99	99	99	99	100	0
3.30	554	99	99	99	100	100	0
3.15	554	100	100	100	100	100	0
3.00	554	100	100	100	100	100	0
2.85	554	99	100	100	100	100	0
2.70	554	99	99	99	100	100	0
2.55	554	99	99	100	100	100	0
2.40	551	100	100	100	100	100	0
2.25	545	100	100	100	100	100	0
2.10	526	100	100	100	100	100	0
1.95	507	100	100	100	100	100	0
1.80	498	100	100	100	100	100	0
1.65	489	100	100	100	100	100	0
1.50	465	100	100	100	100	100	0
1.35	418	100	100	100	100	100	0
1.20	355	100	100	100	100	100	0
1.05	346	100	100	100	100	100	0
0.90	342	100	100	100	100	100	0
0.75	338	100	100	100	100	100	0
0.60	331	100	100	100	100	100	0
0.45	313	100	100	100	100	100	0

TABLE 22

AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

NOTE: A Containment Zone includes the Normal Operating Zone (NOZ) of the specified width and is unbounded on the side of the extended runway centerline away from the adjacent parallel approach. Thus any aircraft that oversteps the containment zone while approaching a dual parallel runway will, by definition, be in the No Transgression Zone.

AIR TAXIS ONLY VIEW 2

TIME PERIOD: 1/24/89 TO 3/20/89 558 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT <500	<550	<600	<650	<700	>700
10.50	447	435	440	444	444	445	2
10.35	457	443	449	450	453	455	2
10.20	461	447	452	452	455	459	2
10.05	467	450	453	459	461	464	3
9.90	474	454	458	462	468	470	4
9.75	480	457	462	467	474	476	4
9.60	484	465	469	475	477	480	4
9.45	486	467	469	476	479	482	4
9.30	490	473	475	479	484	486	4
9.15	493	476	481	484	486	488	5
9.00	494	476	483	484	488	488	6
8.85	497	482	485	486	490	491	6
8.70	502	487	488	490	493	494	8
8.55	507	493	494	495	498	500	7
8.40	510	498	500	500	502	503	7
8.25	513	502	503	504	506	508	5
8.10	515	499	503	505	509	510	5
7.95	518	501	508	510	511	513	5
7.80	519	505	507	512	512	513	6
7.65	522	509	511	511	514	515	7
7.50	523	509	512	513	515	516	7
7.35	526	512	515	518	519	519	7
7.20	528	513	516	520	521	522	6
7.05	531	517	523	523	525	525	6
6.90	538	528	530	532	532	532	6
6.75	539	526	527	532	533	534	5
6.60	540	526	529	533	534	537	3
6.45	542	529	532	533	537	538	4
6.30	545	531	535	538	539	541	4
6.15	547	534	538	542	543	544	3
6.00	548	534	539	542	544	545	3
5.85	549	536	538	544	545	546	3
5.70	550	536	540	547	547	547	3
5.55	553	540	547	550	551	552	1

TABLE 22 (continued)
AIRCRAFT CONTAINMENT WITHIN SPECIFIED CONTAINMENT ZONE

AIR TAXIS ONLY VIEW 2

TIME PERIOD: 1/24/89 TO 3/20/89 558 AIRCRAFT

RANGE (NMI)	NO. OF OBSERVATIONS	NUMBER OF AIRCRAFT <500	<550	<600	<650	<700	>700
5.40	554	544	549	551	552	553	1
5.25	555	543	550	551	553	554	1
5.10	556	542	546	552	555	555	1
4.95	556	542	548	549	553	555	1
4.80	556	543	545	549	550	554	2
4.65	555	541	546	549	550	552	3
4.50	555	544	545	548	550	552	3
4.35	555	545	547	549	550	552	3
4.20	555	543	545	549	551	552	3
4.05	554	543	546	549	551	551	3
3.90	554	546	548	550	551	552	2
3.75	554	548	549	550	550	552	2
3.60	555	550	551	551	551	553	2
3.45	554	549	550	550	551	553	1
3.30	554	550	551	551	552	553	1
3.15	554	552	552	552	553	553	1
3.00	554	552	552	552	553	553	1
2.85	554	551	552	552	553	553	1
2.70	554	551	551	551	553	554	0
2.55	554	551	551	554	554	554	0
2.40	551	549	551	551	551	551	0
2.25	545	545	545	545	545	545	0
2.10	526	526	526	526	526	526	0
1.95	507	507	507	507	507	507	0
1.80	498	498	498	498	498	498	0
1.65	489	489	489	489	489	489	0
1.50	465	465	465	465	465	465	0
1.35	418	418	418	418	418	418	0
1.20	355	355	355	355	355	355	0
1.05	346	346	346	346	346	346	0
0.90	342	342	342	342	342	342	0
0.75	338	338	338	338	338	338	0
0.60	331	331	331	331	331	331	0
0.45	313	313	313	313	313	313	0

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